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DEVELOPMENT DIGEST

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Gordon Donald, Editor; Anthony Pearce-Batten, Associate Editor;
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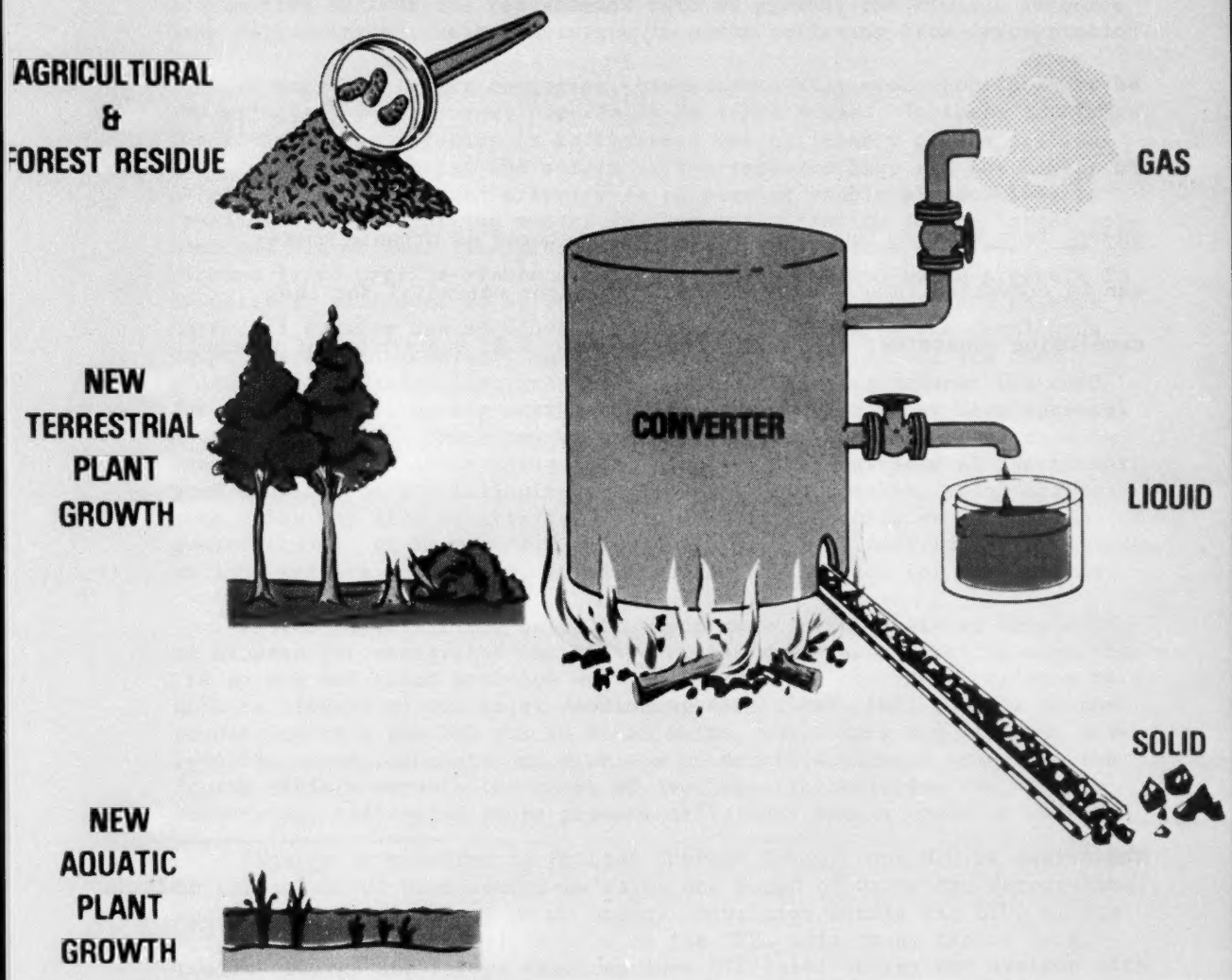
ENERGY FROM BIOMASS

FUELS FROM BIOMASS



Energy from Biomass Sources: solar energy stored as organic matter can be converted into a usable form, with major potential for the developing countries. (Artist's conception: U.S. Department of Energy).

Biomass as an Energy Source

Anthony Pearce-Batten, Associate Editor, Development Digest

Since 1973 rising oil prices and the prospect of future shortages have encouraged efforts to increase the use of renewable energy sources. The April 1977 issue of the Development Digest discussed solar energy in the forms of direct sunlight, wind, ocean thermal sources, and hydro power. But solar energy is perhaps most widely used in an additional form--as biomass. As solar energy converted into plant matter by photosynthesis, biomass includes trees, vegetables and all plants, including aquatic varieties, as well as animal and human wastes. While it is renewable, biomass depends on a destructible production base: when its consumption exceeds its replacement rate of growth, the biomass resource base will contract, as has occurred in areas suffering from deforestation.

In many developing countries, biomass--chiefly wood--continues to be the principal fuel source, especially in rural areas. In these countries, the first energy priority is to increase the efficiency of its utilization,* thereby reducing the strain on the resource base and the threat of deforestation. A second priority is to provide viable alternatives to fossil fuels in supplying energy for industrialization in the larger volumes and higher heat intensities that economic progress requires. If biomass is to provide viable substitutes for petroleum-based products in industry it will need to be converted into high BTU liquid and gaseous forms. A greater use of biomass as an energy source in the developing countries may increasingly make good economic sense as oil and coal prices rise. Nationally, greater reliance on biomass reduces the need for fuel imports, saving scarce foreign exchange for other developmental needs. Locally, biomass may be the only expandable option available in many remote rural areas using local inputs. Although some of the techniques examined in the following articles are very complex, major efficiency gains may also be attained using simpler technologies such as improved stoves, or more modern methods of pyrolysis; anerobic fermentation, an intermediate technology, is also a practical option for rural areas.

In the first article below, Hammond surveys the state of knowledge on biomass for energy and the prospects for relevant scientific advances. The second and third articles analyze large-scale innovative efforts to utilize biomass in two major developing countries: Smil reports on the production of a low BTU gas in rural China, while Yang and Trindade analyze the accomplishments and problems of Brazil's alcohol program. The fourth article surveys the range of available technologies for biomass conversion, indicating where present efficiency levels could be raised.

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*Energy is measured in British Thermal Units: one BTU is equivalent to the amount of heat needed to raise one pound of water one degree Fahrenheit. The efficiency of an energy conversion equals the BTUs of its output (e.g. electricity) divided by the BTUs used up as inputs (e.g. coal). Energy use always involves some BTU loss; energy use systems with one or more conversions can be compared in their efficiency of BTU delivery to users.

Biomass Conversion—A Rediscovered Source of Fuels

Allen Hammond

[With oil and coal costs rising, scientific interest in biomass as an energy source is growing. As a long run source for global renewable energy supplies, the general prospect is favorable. There are a number of weaknesses in current biomass conversion methods, but the area is one in which new research findings are likely to be significant.]

Less than 100 years ago wood was the primary fuel in the United States. Today wood and other forms of biomass, including crop fibers and animal wastes, are still the primary source of energy in rural areas of developing countries, which is to say for most of the world's people. Even in the industrialized areas of the world there is growing interest in renewable sources of energy such as biomass. Yet the conventional wisdom has been that coal and nuclear energy will become the major substitutes for oil as supplies become increasingly scarce, and that biomass can never become a significant source of energy because most of the arable land will be needed for food production.

I would like to suggest that biomass-derived fuels have a key if not a major role to play in world energy affairs. The essential word is fuels -- especially gaseous and liquid fuels. So much of the world's industrial plant and transportation system depends on liquid and gaseous fuels that it is difficult to conceive of a world without oil or natural gas -- and yet dwindling supplies of such fuels in future years is a

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real prospect. Coal, which is the major conventional source of substitute fuels on a global basis, is distributed very unevenly geographically speaking, in that 80 percent of recoverable reserves are located in 3 countries -- the United States, the USSR, and the People's Republic of China. In contrast, biomass is a more widely distributed source of fuels and one for which many developing countries have in abundance the essential resources -- land, water, and sunshine. Even in coal-rich countries, however, biomass may play a role. The difficulties and costs of obtaining clean synthetic fuels from coal have yet to be confronted in practice, and the sheer magnitude of the effort required to replace oil is staggering. To replace just 1 million barrels of oil a day, for example, will require some 20 large synthetic fuel plants of a complexity rivaling nuclear power stations and costing between $1 and $2 billion each if they were to be built today. The primary alternative to synthetic fossil fuels is biomass fuels. Thus, the proper context for estimating the potential of biomass conversion is not comparison with oil and gas at today's prices but rather with synthetic fuels at probably twice today's prices. In that context, biomass fuels are worth further consideration, even for the most advanced industrial economy.

The fuels crisis has already arrived in many developing countries. National payments balances have been strained by the increasing costs of oil, with the result that the use of petroleum fuels is constrained by a shortage of foreign exchange in some places. They are often unaffordable on rural incomes, while a fuel supply of any kind for rural life is exacerbated by growing deforestation in some parts of the world. A new source of fuels from presently unused biomass, or more efficient conversion devices that stretch out present supplies of biomass fuels, are thus not just a long-range prospect but may provide an essential increment of energy without which development cannot proceed. For the longer term, biomass fuels provide a sustainable basis on which to build a fuel supply for those critical functions, such as transportation and certain industries, that are likely always to need liquid and gaseous fuels.

Perhaps the most critical issue in assessing the potential of biomass is that of supply. Is there enough biomass available or potentially attainable to merit consideration as a significant energy option? Is there enough potentially arable land to supply the world's food and still have some left over for producing energy? The answer clearly depends on what assumptions are made regarding the growth of world population. There have been at least two comprehensive studies of the world's potentially arable land (PAL). One study, by Revelle and others for the President's Science Advisory Committee, concludes that the total PAL might reach 2.9 billion hectares, sufficient to produce food for a world of 8 billion people with a substantial margin left over, but not enough for a world of 12 billion people. A second study, by a group at the Agricultural University of Wageningen in the Netherlands, arrives

at somewhat higher figures for total PAL (3.4 billion hectares), sufficient to support the larger population with a little to spare. By comparison, an estimated 1.36 billion hectares are presently under cultivation.

Even with a world population of 12 billion, the potential of biomass is significant. For one thing, the yield of usable grain or other food staples per hectare is only about half the yield of total biomass under a wide range of conditions because intensive agriculture or forestry also produces substantial quantities of unused stalks, straw, bark, and other crop residues. So an all-out effort to grow food or fiber will also yield a significant quantity of biomass waste that is a potential source of fuel. In the United States potentially collectable crop and feedlot wastes have been estimated at about 300 million tons per year (dry weight); with an energy content typically between 10 million and 16 million Btu per ton, this amounts to about 4×10^{15} Btu's (4 quads) per year, or almost twice the U.S. on-farm expenditure of energy in fuels and fertilizer. Thus in theory U.S. farmers could de-couple themselves from conventional energy sources and become largely self-sufficient--a possibility that is attracting renewed interest. In Sweden, the forest products industry already produces 60 percent of its energy needs from waste biomass, and the larger U.S. forest products industry expects to be even closer to energy self-sufficiency by 1990. U.S. wastes and residues alone might in principle provide the energy equivalent of 3 million barrels of oil per day by the end of the century, which is about half the U.S. crude oil import level in 1978. Whatever the practical difficulties in tapping these materials, it is not a negligible source of energy.

Worldwide, the amounts are much greater. In a recent study for the Rockefeller Foundation, Theodore Taylor of Princeton University estimates the worldwide potential of crop wastes and animal manure to be in excess of 3 billion tons a year, with an energy content equivalent to nearly 25 percent of present world energy consumption. This estimate is to be understood in the same sense as mineral resource estimates, however, and not as a proven reserve, since the amount of these resources that is collectable or recoverable is not established. But the magnitude of the potential resource is clearly sufficiently large to warrant serious attention.

A second consideration is that many potential sources of biomass for fuels can be grown on marginal land that is unsuitable for food production, or on bodies of water. Trees, for example, will grow on swampy land unsuitable for crops. Melvin Calvin of the Laboratory of Chemical Biodynamics at the University of California, Berkeley, has proposed the use of Euphorbia, and other species producing hydrocarbons which are refinable into oil, in arid regions. Water hyacinth

and algae have both been proposed as suitable for freshwater farming, and marine kelp farms are being studies as a way of using the oceans themselves to harvest biomass.

A third factor in assessing resources for growing biomass becomes apparent only at the national or regional level. Regardless of the global figures, many individual countries are so well endowed with land, water, and sunshine that fuels from biomass can play a major role in their internal economies and may even become a source of export earnings. This is particularly true for many countries in the world's tropical and semi-tropical belts. Brazil, for example, is planning to replace much of its imported oil with ethanol from biomass over the next 2 decades, and it has the physical resources to produce additional ethanol for export should the world energy market warrant it. There is substantial potential for biomass in the Philippines, in most of Southeast Asia, and in part of Africa.

Yet it must be acknowledged that when it comes to growing biomass as an energy crop, there are still substantial uncertainties. Energy is still not as valuable a crop as food or fiber and cannot compete for prime land. The costs of growing and harvesting raw biomass are usually the dominant cost items in most analyses of energy plantations. For the present, at least, the use of agricultural or other residues, or the co-production of energy and food or fiber in an integrated process, seems to have advantages--a complementary rather than a competitive approach.

The key limitation to growing biomass resources on a large scale is the low efficiency of green plants as solar energy converters. Although the photo-synthetic process has a theoretical efficiency of 6.6 percent in conversion of energy from the sun, the highest yields obtained with the most efficient plant known, 112 tons per hectare with sugar cane, correspond to an efficiency of about 3.3 percent. Even under intensive cultivation most plants produce biomass with an efficiency of less than 1 percent. Clearly there is room for improvement; and it would be shortsighted to assess biomass resources without acknowledging that potential in an era characterized by a revolution in understanding of the fundamental biology of the cell. Rapid advances in research have begun to lay the groundwork for mastering and perhaps altering the molecular mechanisms of genetic and regulatory systems. The application of these new insights to plants and to agriculture are for the most part still to come, but a few examples may give some hints of the future.

Standard agronomical techniques such as selection of superior breeding stock have usually been applied to increase yields of food; selection to enhance total biomass production is just beginning.

Experiments at the University of Georgia and elsewhere with short rotation cropping (3 to 5 years) of sycamores and other rapidly growing species have shown that yields of wood can be as high as 40 tons per hectare--nearly 3 times the productivity of conventional forestry methods. This approach may have particular significance for countries where deforestation is acute. Application of molecular genetic manipulation techniques have given rise to hybrid grains and improved strains of micro-organisms for fermentation, but these techniques are only beginning to be applied to trees and other species of interest for biomass energy. Screening of tree cells growing in culture to select new genotypes in the laboratory instead of by lengthy field trials is still in its infancy, and laboratory fusion of cells to form trees with hybrid vigor has not yet been accomplished. Examples of more advanced genetic engineering include attempts now under way to incorporate the ability to fix nitrogen into non-leguminous plants, and to transfer aerobic fermentation pathways from yeast to more prolific bacteria.

Looking still further to the future are attempts in the U.S., Japan, and Germany to transcend the plant itself and achieve photolysis of water (to produce hydrogen) in cell-free photosynthetic systems or in artificial photochemical membranes. In effect these membranes would be the biochemical analogues of photovoltaic cells. Professor Calvin, for one, takes the optimistic view that such artificial systems will be achievable in the next two decades, and may have efficiencies far in excess of plant systems. Clearly, the upper limits of the biomass resource are by no means fixed and immovable; we may reasonably hope that they will expand with the world's need for fuels to replace oil and gas.

While in the long run the adequacy of biomass sources poses the key problem, the immediate limitations for many potential users of biomass fuels concern conversion technologies. Where biomass fuels cannot substitute directly for conventional fuels, is the technology available to convert biomass into a useable fuel source? As it happens, there is a wide range of conversion equipment and practical experience with biomass conversion, with improvements in sight. The main problem appears to be not a technical one but rather one of information transfer. There is a considerable range of existing bioconversion technologies applicable to both industrial and rural needs, as mention of a few well-established processes and some recent improvements tend to show. The list includes biological processes--both aerobic and anaerobic fermentation, and thermal processes such as partial oxidation, pyrolysis, steam reforming, and direct combustion. These processes have in common that they can be relatively efficient and non-polluting; biomass does not contain appreciable amounts of sulfur or heavy metals, nor does combustion of biomass fuels make a net contribution to the build-up of atmospheric carbon dioxide.

A technology of particular importance for rural development is biogasification with anaerobic fermentation--fermentation in the absence of oxygen. It can use nearly any form of crop or animal wastes as feed, and it produces an intermediate Btu gas composed primarily of methane. Digesters can be built of inexpensive material and do not require a skilled operator. Locally built digesters generally have slow rates of converting biomass into gas, and may recover the energy contained in the wastes with only about 30 percent efficiency; but the use of gas stoves for cooking is estimated to be about 4 times as efficient as direct burning of wood for cooking. In addition, digester residues make excellent fertilizer. Biogasification can thus help reduce the pressure on natural forests, which in many rural areas is leading to rapid deforestation, and can also reduce the need for commercial fertilizers. China is reported to have installed some 6 million digesters in recent years, and they are also being deployed in Taiwan and half a dozen other countries. Biogasification is not necessarily a slow process applicable only to non-commercial uses; a reactor developed at Cornell University has demonstrated gas production 10 times that of conventional digesters of equal volume and with conversion times as low as 3 hours. As such the process is applicable to the feedlot and dairy industries in the United States and elsewhere.

Thermal means of gasifying biomass are also well established, especially partial oxidation--partial burning with limited intakes of air or oxygen--which has a history extending back before 1800. Gas or oil-fired boilers can be fitted to run on gasified biomass produced by partial oxidation techniques. The product from such air-blown gasification units produces a low quality synthetic gas which may require some modification of the boiler to attain the desired heat intensities, but conversion efficiencies of 80 percent--of the energy value of the raw biomass--are routinely achieved. Recent experience with commercial-size units in California indicates that dry biomass wastes can be converted at a cost of about $1 per million Btu. When the costs of the biomass are included, the combined costs of gasified biomass, about $2-4 per million Btu, correspond roughly to the range of costs for natural gas throughout the United States.

Most thermal conversion processes work best with relatively dry biomass, but steam reforming can be applied to wet biomass too. A novel proposal by M. Antal of Princeton University is to couple steam reforming with concentrating solar collectors to generate the steam; this solar powered biomass refinery would produce hydrogen with an energy content 36 percent higher than that of the raw biomass. It might be especially applicable to the manufacture of fertilizer and other chemical products in biomass-rich countries.

Similar processes exist for liquid fuels. Fermentation of sugar crops or grains to produce alcohol is not a new technology. In recent years, however, work at the Centro de Technologia Promon in Brazil has established an enzymatic process for degrading starch from cassava to fermentable sugars, and a recent study suggests that ethanol production based on cassava can be a net producer of energy even with yields as low as 14 tons per hectare, typical of unorganized agriculture. Dry biomass such as wood can be converted to methanol by a well-known catalytic process following partial oxidation to synthesis gas. A major private consulting study in the United States recently forecast the emergence of methanol as a major fuel, especially for electric utility gas turbines, and as a chemical feedstock, suggesting that there will be a ready market for methanol from biomass as well as from fossil fuels.

Even direct combustion of biomass, which must be the oldest energy technology known to man, is benefiting from some new and rediscovered technology. Major boiler makers in the United States now offer commercial systems for wood-firing boilers either alone or in combination with other fuels. New equipment for pelletizing wood and thus making it a more uniform fuel for industrial applications is coming into the marketplace, and development is underway at Georgia Institute of Technology of a transportable pyrolyzer that can produce a charcoal-like solid fuel from forest or crop wastes.

In addition to the energy potential of biomass, there is growing interest in its use as a substitute for petroleum-based materials in a number of products. The production of fertilizer in anaerobic digesters has been mentioned; other possibilities include the production of ethylene from ethanol, and furfural from wood. Feedstock use may have some economic advantages over simple bioconversion, since chemical products are generally higher priced than the energy product. In the United States, major petrochemical firms are already studying the potential of biomass feedstocks; R. S. Wishart has identified four crop groups capable of supporting an industry equivalent to one billion pounds of ethylene: sugarcane, cellulosic wastes, corn, and sorghum. Developing countries that are rich in biomass have an opportunity to develop chemical industries based on that resource in advance of many industrial countries having a heavy commitment to existing process equipment, and thus perhaps to become the biochemical leaders of the future. Ethylene from ethanol, for example, may already be economically feasible in countries like Brazil.

As fossil fuels become less abundant, renewable sources of energy and materials will be of growing importance. Biomass is such an obvious and ubiquitous resource that its energy potential has been largely overlooked. Indeed the non-commercial sources of energy that are the mainstay of most rural life are rarely included in summaries

of world energy use, and in fact the magnitude of the non-commercial supply is not accurately known in most areas and must be inferred from the rate of deforestation or other evidence. Yet non-commercial energy is certainly a major factor which could increase in importance if conversion technologies more efficient than open burning can be employed, and with more rational use of available wastes and residues. Any country contemplating the expense and difficulties of synthetic fuels from fossil sources should certainly consider the potential and advantages of biofuels as well. Not the least of these advantages are well-established conversion technologies that are frequently economical on a far smaller scale than most conventional energy facilities, and the potential for creating new agricultural employment and stabilizing rural populations. Activity in basic research applicable to bioconversion shows signs of major achievements in coming years, so that the constraints on bioenergy are likely to become less restrictive. In short, bioconversion promises to be a growth field. Fuels from biomass have significant potential for short-term contributions to both energy and development, and they may play a crucial role in the fuel-short world of several decades hence.

[Extracted from a paper delivered to the Interciencia Association/ SBPC Symposium on "Energy and Development in the Americas," Santos, Brazil, March 13-17, 1978.]

The Brazilian Gasohol Program

Victor Yang and Sergio C. Trindade

[Brazil embarked in 1975 on am ambitious program to produce alcohol for mixing with gasoline to reduce its dependence on costly imported petroleum. Initially alcohol output rose sharply; if the program is to succeed in its larger objectives, alcohol production costs must be reduced by new technology.]

Brazil's accelerated industrial development during the last two decades has been accompanied by an increasing demand for imported energy, particularly petroleum. In 1976, domestic energy sources accounted for only 60% of the country's primary energy consumption. Lagging domestic petroleum production, coupled with a heavy dependence on liquid fossil fuels for transportation, led to a petroleum import bill of almost $4 billion in 1977. This alone represented 31% of Brazil's total import expenditure, and surpassed export revenues generated by traditional items such as coffee and sugar. Since the petroleum price rise in 1973, Brazil has faced problems with balance of payments and a slowdown in the country's GNP growth rate.

Petroleum accounts presently for roughly 43% of Brazil's primary energy consumption. Domestic production in 1977 supplied only 16% of the country's petroleum needs. In a period of roughly a decade, petroleum has displaced biomass as the major primary energy source, as seen in Figure 1. Nevertheless, hydropower and biomass are important energy sources in Brazil even today. In 1977, roughly 25% of total primary energy consumption was in the form of hydroelectricity whereas biomass accounted for about 28%. Wood, sugarcane bagasse, charcoal, and fermentation alcohol (ethanol) are the traditional biomass fuels in Brazil.

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The Brazilian Experience with Alcohol as Fuel

Gasohols--gasoline and alcohol fuel blends--have been used in automobiles for decades in Brazil. The earliest recorded experiments with gasohols date back to the 1920s. Compulsory alcohol addition to gasoline to a level of 5% was introduced in 1931, motivated mainly by the government's interest in stabilizing the sugar industry, one of the foremost sectors of the Brazilian economy. Excess supplies of molasses and sugar were converted to alcohol in distilleries attached to sugar mills. The alcohol content in the gasohols, however, varied considerably, depending on the domestic and international market for sugar and molasses as shown in Table 1 and Figure 2.

FIGURE 1

THE BRAZILIAN PRIMARY ENERGY PROFILE

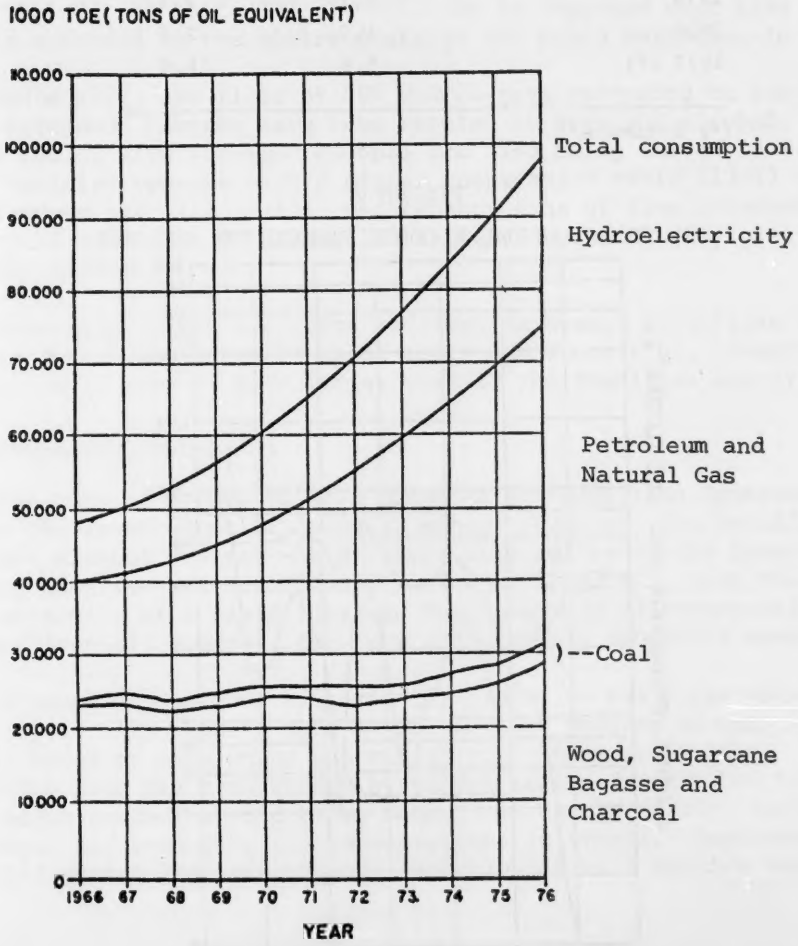


TABLE 1

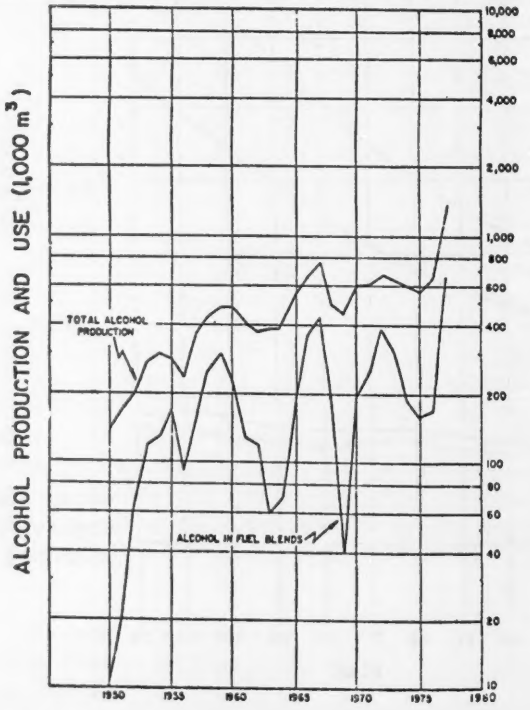
ALCOHOL CONTENT IN BRAZILIAN GASOHOL-HISTORICAL

	ANNUAL AVERAGE (% vol.)	
	National	São Paulo State
1967	6.2	13.5
1968	2.3	5.1
1969	0.3	0.4
1970	1.9	4.6
1971	2.5	5.8
1972	3.5	8.6
1973	2.5	7.0
1974	1.4	3.1
1975	1.1	2.4
1976	1.2	2.6
1977 (*)	5.6	10.0

(*) Estimate

FIGURE 2

BRAZILIAN ANNUAL ALCOHOL PRODUCTION AND USE



The National Technology Institute (INT) was the first to experiment with use of gasohols in automobiles, in the 1920s. Between 1974 and 1976 CTA - the Air Force Technical Center - investigated the performance of Brazilian automobile engines fueled with gasohols containing varying amounts of alcohol. The overall conclusion was that all existing Brazilian standard internal combustion engine vehicles, when fueled by gasohol containing up to 20% of alcohol by volume, did not lose performance compared with straight gasoline operation. Furthermore, no engine modifications were required, partly because most Brazilian engines operate with a fuel-rich mixture. Moreover, the use of an alcohol blend raises the octane rating of the average Brazilian gasoline. Climatic conditions do not hamper the performance of gasohol-fueled engines in Brazil, mainly because ambient temperatures are seldom below freezing.

In 1977 the City of Saõ Paulo, with 1.3 million internal combustion vehicles, and other large urban centers were supplied with gasohol containing close to 20% alcohol. It is expected that this pattern will be extended to the entire State of Saõ Paulo beginning in 1978.

Since 1977, the fleet of 400 Volkswagens belonging to the Saõ Paulo Telephone Company have been running on straight alcohol. Vehicles fueled with straight alcohol are also being tested in Brazil. These vehicles operate with a higher compression ratio (13:1) than the standard practice (7:1). Maintenance vans of five telephone and electrical utilities totalling 520 vehicles operate today with straight alcohol.

Currently, there are tests underway in Brazil to utilize alcohol also in Diesel engines. If these tests are successful, fermentation alcohol could play an even larger role in the Brazilian energy market.

Background and Objectives

The turn of events in 1973 prompted the Brazilian government to foster the development of domestic energy sources. The Brazilian National Alcohol Program--hereinafter referred to as the Brazilian Gasohol Program--was established in November of 1975, with the primary objective of a rapid increase in the supply of fermentation alcohol from all sources, for fuel and chemical feedstock uses.

Alcohol production, historically linked to the sugar industry, should gradually develop into an independent venture in many locations, based on both sugar and starch-containing feedstocks. This departure from the traditional byproduct status for alcohol to one as a major product should bring about important economic, social, political and technological repercussions in Brazil. Improvement of both industrial and agricultural technologies will require intense

R&D and managerial efforts, geared to alcohol production on an unprecedented scale. In addition to molasses, sugar cane juice and cassava or manioc (from which tapioca is made) are alternative feedstocks for Brazilian distilleries. Babassu, a native coconut, and sweet sorghum may also become alcohol feedstocks in the future. New alcohol production from fermentation sources may lead to agro-industrial activities in remote areas. The energetics and economics of alcohol production are also noticeably different in the case of direct alcohol production in the so-called independent distilleries--those not connected with production of sugar or any other commodity.

The Program's expected economic objectives include savings in scarce foreign exchange through substitution of imported fossil fuel, and strengthening of the internal market through a more intensified usage of domestic production factors. For example, Brazilian industry is supplying most of the equipment needs of the new distilleries. Important social benefits expected from the Program include creation of jobs at the farm level and consequently a possible reversal of the urban migration trend in the long run, improvement in income distribution, and a more balanced development over the country. Political implications of the Program include the occupation of idle and underutilized territories, and the long term prospect of relative independence from external sources of energy and chemical feedstocks.

Status of the Program

Alcohol production has increased substantially in Brazil since the implementation of the Gasohol Program. In 1977, low international sugar prices, coupled with government incentives, contributed to a 100 percent increase in production levels to 1.5 million cubic meters. This production increase was achieved mainly by using idle capacity in existing distilleries, and by the allocation of sugar surpluses for alcohol production. As of July 1978, 187 more distillery projects had been approved by the National Alcohol Committee, adding some 4.1 million cubic feet per year of additional capacity, at a cost of over $2 billion in terms of industrial investment alone. Roughly 14 percent of this added capacity is to be achieved by expanding existing facilities; the remaining 86 percent is to come from new facilities. This additional capacity should be in operation within 4 years at the most. In 1978 alone, approximately 39 new distillery projects (including expansion of existing units) were scheduled to come on stream, representing a combined additional capacity of close to 950 thousand cubic meters per year.

In terms of carbohydrate feedstock, molasses or sugar mill distilleries account for 53% of the authorized additional capacity. Independent distilleries such as sugarcane juice distilleries account for 38% and cassava distilleries for 8%. To date one babassu distil-

lery with a capacity of 9 thousand cubic meters per year has been approved. Cassava can be grown under soil and climatic conditions unsuitable for sugarcane. The first cassava distillery with a capacity of 60 m^3/day was constructed by the government oil corporation, Petrobras, in association with INT (National Technology Institute) for demonstration purposes, and is presently undergoing start-up tests.

The Brazilian Alcohol Market--an Overview

By 1985, total fermentation alcohol production in Brazil is expected to be in the range of 4-6 million cubic meters. If all the alcohol thus produced were to be used in fuel blends, it would supply approximately 2% of Brazil's primary energy requirements in 1985, according to projections by Ministry of Mines and Energy. Both cassava and sugarcane yield 3.3 cubic meters annually per hectare. Consequently, a production of 5 million m^3/yr by 1985 would require at least 1.5 million hectares. This area is smaller than the area currently under sugar production in Brazil and represents less than 0.2 of the surface of the country.

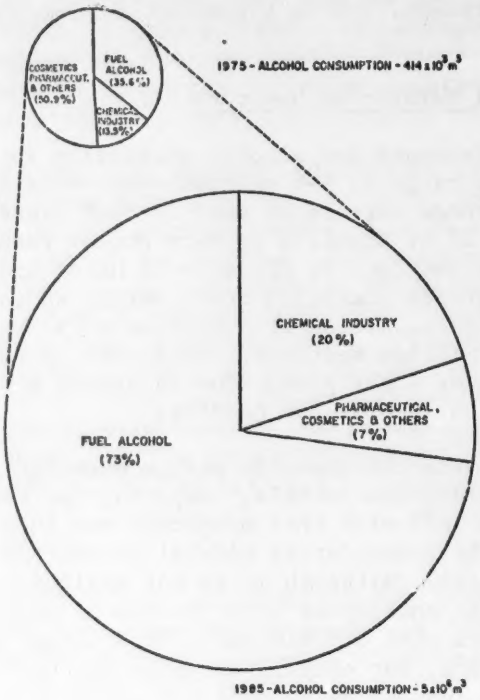
Figure 3 illustrates the dramatic change expected in the Brazilian alcohol consumption profile, comparing the sectoral demand for alcohol in 1975 with that projected for 1985. In the short term, most of the fermentation alcohol production is being used to replace gasoline. Although it is not explicitly stated as a goal, this program is consistent with the aim of nation-wide availability of gasohol with 20% alcohol. This target appears feasible by the mid 80's, but only if the pace of the Gasohol Program is accelerated. Industrial alcohol not going to the fuel market is now used as a solvent and cleansing agent in the pharmaceutical and cosmetics industry, and as a feedstock for the chemical industry. The demand for alcohol is expected to grow much faster in the chemical industries between now and 1985 than in the pharmaceutical and cosmetics industries, as indicated in Figure 3. The existence of a guaranteed market for fuel alcohol in the near term will constitute a major incentive for establishing new distilleries, and will greatly influence the location of these units.

Process Technology

The production of alcohol from sugarcane begins with a juice preparation step, which occurs at the sugar mills. The juice is then fermented, using yeast, before being distilled. The basic products of the distillation process are absolute or pure ethanol, hydrated or 96% pure ethanol, and small quantities of fusel oil which is used in the manufacture of explosives and pure amyl alcohols. Large quantities of bagasse and stillage are produced as by-

FIGURE 3

BRAZIL ALCOHOL CONSUMPTION BREAKDOWN BY END-USE


1975 - ALCOHOL CONSUMPTION - 414 x 10³ m³
CHEMICAL INDUSTRY (20%)
PHARMACEUTICAL, COSMETICS & OTHERS (7%)
FUEL ALCOHOL (73%)
1985 - ALCOHOL CONSUMPTION - 5 x 10⁶ m³

products of the process. Table 2 shows the materials balance in a typical independent sugarcane distillery, and also in a cassava distillery.

Alcohol production from cassava entails additional preparation stages to convert the starch present in the roots into fermentable sugars. After the initial washing and size-reduction steps, the starchy mash is liquefied (converted to dextrines) through a combination of thermal (steam cooking) and enzymatic actions. Alpha-Amylase is added prior to the cooking step. The liquefied mash is in turn hydrolyzed to fermentable sugars in the saccharification step through the action of the enzyme glucoamylase. The fermentation and distillation steps are similar to the sugarcane-derived alcohol. Stillage is the major by-product, with fusel oil and cassava skin and fibers generated in lesser amounts.

TABLE 2

Material Inputs, Outputs and Utility Demands in Distilleries Using Sugarcane and Cassava as Feed Stocks: Amounts per Cubic Meter of Pure Alcohol

Inputs	Unit	Sugarcane	Cassava
Sugarcane	m. tons	15.1	--
Cassava	m. tons	--	6.8
Chemicals	kg	46.2	55.2
Enzymes	kg	--	4.7
Outputs			
Hydrated (96%) Alcohol	liters	50.0	50.0
Fusel Oil	kg	4.8	4.8
Stillage	m. tons	12.0	11.5
Bagasse	m. tons	3.8	--
Skin & Fibers	kg	--	426.4
Carbon Dioxide	kg	760.0	760.0
Utility Demands			
Clarified Water	m^3	13.6	22.0
Cooling Water	m^3	44.7	5.3
Boiler Feed Water	m^3	--	4.2
Steam	m. tons	8.9	6.2
Electric Power	Kwh	--	448.0
Compressed Air	Nm^3	80.0	82.9
Fuel (bagasse or wood)	m. tons	4.0	1.7

Presently, most of the sugarcane-based distilleries burn their bagasse as boiler fuel for steam raising and electricity generation, and the fusel oil is sold. Stillage disposal practice and outlook are discussed below. Table 2 also shows the utility consumption of a typical independent sugarcane distillery and a hypothetical cassava distillery. Large energy consumption is incurred, especially in the distillation step. In sugarcane-based distilleries, bagasse availability is adequate to provide for energy self-sufficiency. The situation in cassava distilleries is different due to the absence of "bagasse" if only the starchy roots are processed. However, if the total cassava plant is harvested the stalks may be a source of energy.

Process Economics

Table 3 shows the economics of alcohol produced from cassava and from sugarcane, considering independent distilleries of the same daily capacity (150 m^3/day). Conservative design premises were adopted for the hypothetical cassava distillery which was compared to a typical independent sugarcane distillery. Annual capacities differ due to the limited sugarcane harvesting season. The cassava distillery turns out to require a fixed investment which is 20% higher than an equivalent independent sugarcane distillery because of the additional equipment needed for liquefaction and saccharification. But the larger alcohol inventory necessary in the independent sugarcane distillery (due to the fuel alcohol legislation) entails a considerably higher working capital for the sugarcane distillery. As a result, total investments differ by about 10%.

The alcohol costs were computed assuming a return on investment of 12%/yr. The total costs of cassava alcohol and sugarcane alcohol differ by less than 10%. The fuel alcohol administered price, currently at \$317 - 327/m^3 (\$1.20 - 1.24/gal), is lower than the calcu-

TABLE 3

ECONOMICS OF PRODUCTION OF ANHYDROUS ETHANOL FROM CASSAVA AND SUGARCANE

Basis: 150 m^3/d cassava distillery operating 330 days/yr (49,500 m^3/yr)
150 m^3/d sugarcane distillery operating 180 days/yr (27,000 m^3/yr)
Exchange rate: Cr \$18,00/US \$1.00

	CASSAVA HYPOTHETICAL DISTILLERY		SUGARCANE DISTILLERY	
Investment				
Fixed Investment \$ million	15.8		13.3	
Working Capital \$ million	1.2		2.2	
	17.0		15.5	
Composition of Costs				
Feedstock:	\$/m^3	(%)	\$/m^3	(%)
Cassava Roots at \$33.3/ton (a)	228	60.1	-	-
Sugarcane at \$13.6/ton (a)	-	-	204	57.0
Enzymes, Chemicals and Utilities	60	15.8	6	1.7
By-products (b)	(16)	(4.2)	(15)	(4.2)
Labor	13	3.4	15	4.2
Maintenance Materials, Operating Supplies, Insurance & Administrative Expenses	18	4.8	25	7.0
Taxes (c)	15	4.0	24	6.7
Depreciation	32	8.4	49	13.6
Net Operating Profit (d)	29	7.7	50	14.0
Calculated Cost as Fuel, FOB Distillery	379	100.0	358	100.0

NOTES: (a) Includes value added tax (sugarcane) and social tax (sugarcane and cassava)
(b) Difference between the cost of direct application of stillage as fertilizer and the credit of sales of hydrate ethanol and fusel oil
(c) Includes income tax and social tax
(d) Return on investment of 12%/yr, based on the annual sum depreciation and net operating profit, and 15 year operational life for the distillery

lated costs for both cassava and sugarcane alcohol, which are in the range of $360 - 380/m^3$ FOB distillery ($1.36 - 1.44/gal). If, however, the subsidized financing available under the Program is considered, fermentation alcohol economics could be marginally attractive.

A breakdown of the alcohol costs shows a striking similarity in the sugarcane and cassava distilleries. Agricultural feedstock accounts for the largest fraction of the estimated selling prices. Hence, high sensitivities of alcohol economics to agricultural and distillery yield increases are probable. The by-product credit in both cases appears small, according to Table 3. Note, however, that raw stillage was valued mainly as a mineral fertilizer substitute. If the proper value of the organics in the stillage is assigned, or other more efficient stillage upgrading methods are considered, it may be possible to generate a higher net by-product credit. Moreover, excess bagasse in independent distilleries above steam raising needs may be a source of additional by-product revenues under appropriate pricing and market conditions.

Process Energetics

The net energy ratio (NER) analysis relates the energy content of an output stream to that of its inputs. The energy accounting includes all energy consumption associated with input streams, such as the fossil fuels consumption related to fertilizers consumed in cultivation of sugarcane or cassava. Solar energy of course is the major energy input, but it does not enter NER calculations because it is freely available. The NER analysis of alcohol production includes both agricultural and industrial subsystems; the most important inputs are firewood and stalks (for steam raising) and electricity. It has been estimated that for a typical 150 m^3/day alcohol distillery, the NER value for the best system configuration could reach over 8.0 for both cassava and sugarcane alcohol.

Ecological Issues

Stillage is the largest by-product by volume of alcohol distilleries. Generated at 12 to 13 times the volume of the alcohol produced, total stillage output by the Brazilian distilleries in 1977 was on the order of 20 million cubic meters. Because of its high content of soluble organics and inorganics, stillage has a high pollution potential if discarded into rivers. For example, the total Brazilian stillage output in 1977 was roughly equivalent to the sewage corresponding to 50 million inhabitants. But stillage normally does not contain pathogenic bacterias or viruses, nor heavy metals or polychlorinated organics; recovery of its materials is thus a potentially attractive undertaking. It is technically feasible to convert stillage into marketable products such as fertilizers and feed ad-

ditives, or into methane as a supplementary energy source. Economics will ultimately determine the choice of stillage treatment process and the product form.

Presently there are two stillage treatment processes in use in Brazil. The most widespread practice is lagooning. The other process takes advantage of the fertilizer value of stillage: raw stillage is sprayed over the sugarcane fields, thereby reducing or eliminating the mineral fertilizer requirements. The increasing size and numbers of independent distillers will call for more efficient and economic means of stillage utilization. The emergence of a market for stillage products may improve the alcohol distillery's overall economics.

Problems and Opportunities

The Brazilian gasohol program faces a number of challenges in the near to long term. Uncertainties of various kinds are plaguing the program, such as the following:

- lack of a clear political decision and commitment to carry the program to its fullest extent;
- lack of a clear commitment of the Brazilian auto industry to gasohol or to straight alcohol, and to the use of alcohol in diesel engines;
- questions relating to the concentration, as against dispersion, of new distilleries and income all over the country;
- the large required investment, high costs, and marginal economics of fuel alcohol production;
- the limited availability of subsidized financing;
- the possible development of new agricultural and industrial technologies, and their effects, as alcohol evolves from a sugar by-product to an energy product in the fuel market.

Critics of the program have cited alternative and apparently cheaper short term energy strategies. For example, a fuel oil conservation program could save Brazil in 2 years as much petroleum as would the gasohol program in 7 years, and for a much smaller investment. It appears that reduction in the investment and operating costs are essential if the Program is to attain the scale proposed. In addition, the movement and storage of large volumes of agricultural feedstocks, stillage and alcohol pose considerable technical and managerial problems. Proper siting and coordination of both the

agricultural and industrial operations are important for the ultimate success of distillery ventures. Brazil's agricultural base will need strengthening if alcohol feedstocks are to achieve more acceptable quality standards and cost levels. Plant genetic research, and optimization of farming practices, appear to demand considerable R&D effort in the upcoming years.

Improvement in the distillery's process and operations technology may be the key to the feasibility of alcohol production. Large scales of operation generally favor continuous processing. Thus an exploration of methods of continuous liquefaction and fermentation warrant concentrated R&D efforts. An energy-saving separation process, such as reverse osmosis, may eventually substitute for conventional distillation and evaporation operations.

The State of São Paulo alone accounted for at least 2/3 of Brazil's total alcohol production in 1977. If other states do not keep up with the alcohol producing pace of São Paulo, an even more serious polarization effect may result. This scenario would go against the policy of industrial decentralization, one of the underlying objectives of the Brazilian Gasohol Program. In the near term, therefore, alcohol distribution is a challenge to the Brazilian authorities: already the excess fermentation alcohol in São Paulo (after allowing for statewide usage of gasohol with 20% alcohol) has to be trucked to neighboring states. It is possible that local alcohol supply/demand problems in the fuel market coupled with local shortages and escalating prices of petroleum derivatives, may lead to increased usage of alcohol in the Brazilian chemical industry as feedstock. Ethylene, acetic acid and octanol are currently manufactured from alcohol. A number of new units are being planned.

Conclusions

The scope of the Brazilian Gasohol Program is bound to have profound implications for the country in the long run. If the Program is successful, Brazil could become more self-sufficient in both energy and technology in addition to benefiting from economic, social and political improvements. Agriculture may become the basis for Brazil's needs not only for food, fiber and feed, but also for chemicals and energy--due to a favorable combination of land area, latitude, population and stage of development. The substantial increase in alcohol production achieved since the start of the Brazilian Gasohol Program appears to indicate that large-scale substitution of fossil fuels might be achieved and sustained in the near future. Nevertheless, problems with alcohol economics, agricultural and industrial technologies, and distribution challenge Brazil's technical and managerial skills.

The economics of direct alcohol production in independent sugarcane and cassava distilleries appears to be marginal at present, even with Government subsidies. It is not surprising, therefore, that most of the fermentation alcohol production today derives from sugar mill distilleries with alcohol playing a by-product role. A depressed international sugar market has favored conversion of sugar and molasses to alcohol, and has contributed to the high production levels already recorded. But alcohol production from sugar mill distilleries cannot provide the quantities required for fuel and chemical usage on a national scale. Moreover, difficult-to-predict sugar market fluctuations, and distribution problems may be critical. Already the State of São Paulo, the largest sugar producing state, faces a surplus of alcohol which needs to be trucked to other states. A sustained large-scale alcohol production, therefore, can only be achieved if a large number of independent distilleries, based on locally available feedstocks, are erected throughout the country. In this context, improvement in technologies for conversion of sugar and starch-based feedstocks are basic to the economic feasibility and long-term success of the Brazilian Gasohol Program.

Gasohol programs, however, should not be generally recommended to all countries in the world. Probably only those countries with sufficient agricultural land, sunshine and water resources to grow surpluses of food, feed and fiber could resort to gasohol programs to help alleviate energy problems.

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Biogas Production in China

Vaclav Smil

[The rapid expansion of biogas digesters in south China, particularly in Szechwan province, is described; it represents a major current innovation in biomass utilization for energy.]

Since the early 1970s the technology of producing biogas from organic matter has been spreading throughout some of China's rural areas. The procedure is, at least in principle, rather simple, and the processes involved are well known.

Animal dung, human wastes, pieces of vegetation (crop stalks, straw, grass clippings, leaves), garbage and waste water are sealed up in insulated containers (digesters, pits) and left to decompose. Digestible organic materials (liquids, proteins, and most starches) are broken down by acid-producing bacteria and the volatile acids are, in turn, converted by anaerobic methanogenic bacteria into a gas which is typically composed of 55 to 70 percent methane, 30 to 45 percent carbon dioxide and traces of hydrogen sulfide, hydrogen and nitrogen. Besides yielding the versatile low pressure medium-caloric biogas (between 5,300 and 6,300 kilocalories per cubic meter; pure methane has 9,345 kilocalories per cubic meter), the process yields an organic fertilizer of outstanding quality. Implementation of the technology also results in considerable improvement in sanitation in the rural areas.

Small-scale non-commercial production of biogas was tested in India and in Europe in the late 1930s, but has received greater worldwide attention only

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during the past decade. The biogas is also called "dungas" and "gobar gas" in India. The Chinese reports use mostly the name "marsh gas."

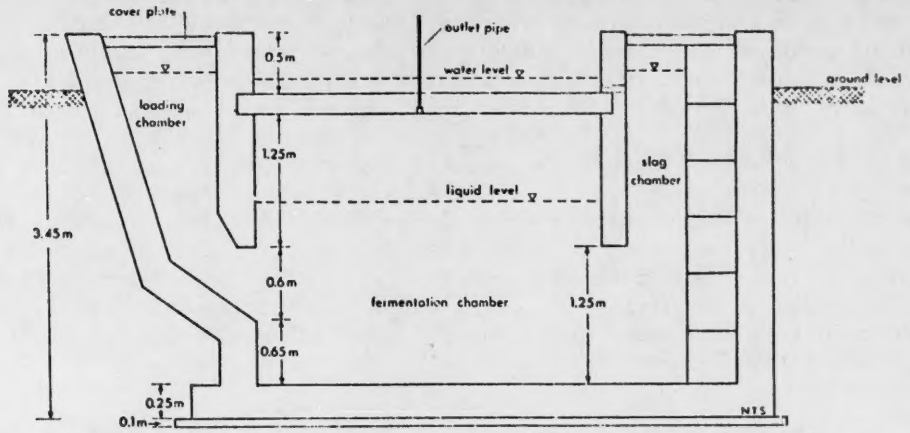
The first attempts by the Chinese date from the Great Leap period; but a massive, and apparently well organized, campaign to popularize the technology started only a few years ago in Szechwan province, where the number of fermentation pits has been growing at a very fast rate. By the end of 1973 more than 30,000 tanks had been built throughout the province. The total was 209,000 a year later (with 169,000 containers used for biogas production) and by the middle of 1975 twice as many (410,000) digesters were reported to be in operation. Over 1.3 million digesters were built in the first six months of 1976, and more than 2.8 million peasant families in Szechwan were producing their own biogas by the beginning of August 1976. The leading area in the province, and in all of China, is Mien-yang county where, as of July 1975, some 60,000 pits were completed and another 20,000 were under construction, with more than 60,000 peasant households using biogas for cooking and lighting.

Recent reports from China stress the advantages of the method. Biogas production is undoubtedly an economical way to solve fuel problems in many rural areas, as it conserves local fuelwood or imported coal and kerosene, upgrades vegetal refuse and human and animal wastes into an excellent fertilizer, and contributes to a cleaner environment. With minor equipment modifications, biogas can be used to power internal combustion engines and as a substitute for diesel oil in small electric generators. And it is, of course, a clean and convenient fuel for household cooking and lighting.

Consequently, the biogas campaign continues to spread the technology throughout the country. In May 1978 there were 5.76 million digesters in over 1,000 counties in China, most of them (4.3 million) in Szechwan where they provided some 20 million peasants with cooking fuel. According to the long-range plan published in summer 1978, China should have 20 million biogas digesters in 1980 and 70 million by 1985; this implies their use by about 70 percent of peasant households. Biogas digesters are now increasingly used even in the cold north, but their efficient operation in higher latitudes is limited by the climate (see below).

The effort is supported through national conferences organized by the Chinese Academy of Sciences, State Planning Commission and Ministry of Agriculture and Forestry; by the training of technicians--100,000 of them in Szechwan alone; by the manufacture of simple gas stoves and lamps, rubber or plastic pipes, and pressure gauges; and through the design of differently shaped fermentation pits. Construction of a typical 10 to 15 cubic meter digester, consisting of loading, fermentation and slag compartments is becoming simpler and cheaper (see Figure 1). For a 10 cubic meter unit, cement consumption was reduced from 400 kilograms to less than 100 kilograms, and the cost dropped from 100 to 40 yuan (from about $50 to $20). For

FIGURE 1: CROSS-SECTION OF A TYPICAL SZECHWANESE BIOGAS DIGESTER



Besides yielding the biogas, a clean, efficient and non-exhaustible source of energy, the digesters also yield an organic fertilizer of outstanding quality and contribute to a cleaner environment. This cross section of a typical Szechwanese biogas digester is not drawn to scale. Flow of the water through a small hole (5 mm in diameter) in the wall separating the gas and the slag compartment keeps a relatively stable pressure inside the digester. The outlet pipe (metal or hard plastic) is about one meter long with an inside diameter less than 2 mm.

Source: *K'o-hsuen Shih-yen*, May 1973, p. 32.

comparison, most Chinese peasants earn less than 100 yuan per person per year from communal activity on a farm.

When properly managed, a digester is sufficient to supply a South Chinese family of five with enough fuel for cooking and lighting. Peasants are encouraged to build their own pits, using cement, rocks or bricks. Larger digesters are built collectively to produce biogas for fueling water pumps, farm processing machinery and small-scale power generation.

But biogas production is not without problems. Certainly the most important limitation is the impossibility of using it efficiently in colder regions of the country because of the thermal requirements of the fermentation process. Methanogenic bacteria reproduce rather slowly and are very sensitive to environmental changes. During mesophilic fermentation--that is, fermentation of organisms which thrive best at a moderate termperature--the temperature should be optimally at 28° to 45° C, without fluctuating more than ± 2°C. Thermophilic fermentation--of organisms which thrive at an elevated temperature, 55° to 60° C--is even more temperature sensitive. Psychrophilic bacteria--which thrive at a low temperature(0° to 7° C)--are unsuitable for digester biogas production.

The Szechwan Basin and the sourthern provinces (Fukien, Kwangtung, Kwangsi and sourthern Yunnan), which have high average ambient temperatures and less than five freezing days a year, are best suited for the

fermentation of the organic matter involved. The possibilities of widespread economic biogas generation in areas with more than 100 freezing days a year are practically nil--notwithstanding any claims of "encouraging results." (High, steady digester temperatures can be, of course, maintained even in a cold climate; but the heating may easily require more energy than is released in biogas by methanogenic bacteria.)

Even in a warm climate with concrete digesters well insulated in dry soil, a considerable drop in efficiency and eventual cessation of biogas production can occur for several reasons. Acid levels may become excessively high, requiring applications of lime for a return to neutrality. The ratio of carbon to nitrogen may rise, especially where crop residues are used, requiring additional inputs of nitrogen. The balance between acid-forming agents and methane producing agents can be upset in the absence of sufficient liquids.

According to the Office of Science and Technology of Mien-yang county, Szechwan, the best combinations for digester loading are 10 percent human waste, 30 percent animal waste, 10 percent straw and grass, 50 percent water; or 20 percent human waste, 30 percent hog manure and urine, and 50 percent water; or 10 percent each of human and animal waste, 30 percent marsh grass and 50 percent water.

Other problems associated with biogas generation involve sand accumulation, scum build-up and removal, and collection and loading of human and animal waste. The contents of the digester must be stirred regularly to break the dried scum on the top of the liquid and to mix the loaded materials. The accumulated slag must be removed, and the fermenter thoroughly cleaned at least twice a year.

On the assumption that digesters can operate viably only south of the Yellow River, I have estimated the maximum potential of biogas generation in China at some 60 billion cubic meters annually, equivalent to about 50 million tons of hard coal. The full realization of this potential is, of course, highly unlikely. However, as approximately three-quarters of China's rural population (at least 500 million people) live in areas where biogas production is viable, all attempts to introduce this technology into suitable regions are most desirable. And, in spite of the associated problems, well-managed biogas production offers a clean, efficient and--what is certainly most important--a non-exhaustible source of energy which can be tapped inexpensively to benefit indefinitely a large segment of China's population.

[Extracted from "Intermediate Energy Technology in China," World Development, Vol. 4, No. 10-11, pp. 929-937, November 1976, Copyright © Pergamon Press Ltd., Oxford, England. For reproduction in any country, permission is required from Pergamon Press Ltd., Headington Hill Hall, Oxford OX30BW, England]

Technologies for Converting Biomass Into Energy: A Survey

J. G. Bene, H. W. Beall, and H. B. Marshall

[In most countries various forms of biomass are available, or could be made available; but because of their bulk and relatively low heating value they cannot be economically transported very far from the source. Methods are therefore needed for converting bulky biomass into clean, efficient, energy-intensive fuels which can be used as replacements for petroleum products in providing heat and light in the rural villages, and in providing fuel for small engines. It is expected that the economics of some biomass conversion processes, especially those which are labor-intensive, may be quite favorable in the developing countries.]

Energy Usage in the Developing Countries

The energy requirements of a family in a rural village of a developing country are relatively small compared to those of an urban family in highly industrialized society. These requirements also vary considerably from one country to another, as does the type of fuel available. We shall treat India as a representative example of a developing country where there is a serious fuel shortage; it is one of the few countries where detailed energy consumption information is available. According to the 1971 census, 80% of the population in India lives in rural villages. Their pattern of fuel consumption is shown in Table 1. Commercial fuels, which are common in urban areas, only account for 5.4% of the total energy needs of the rural population. The census also found that only 33% of the firewood, 2% of the dung cake, and none of the vegetable wastes are bought or sold; thus, 80% of the fuel requirements of the villages is essentially free. However, the effective utilization of these fuels is believed to be very poor because of their very low system efficiency.

The authors were consultants for the Government of Canada's International Development Research Center, Ottawa.

TABLE 1

PATTERN OF FUEL CONSUMPTION IN RURAL INDIA

Fuel	Percentage share
A. Commercial	
Soft coke	1.6
Kerosene	3.8
Electricity, gas, etc.	negligible
B. Non-commercial	
Firewood	58.6
Dung cake	21.0
Vegetable wastes	15.0
Charcoal, vegetable oil, etc.	negligible
Total	100.0

The traditional use of cow dung as a fuel in India has been increasing because of the growing scarcity of firewood and other fuels, and is now believed to require 30-50% of the total dung available. This wasteful practice is of concern to the authorities because it deprives the soil of an important source of nutrients and organic matter which are needed for improving fertility.

The various technologies for converting biomass into a more convenient form of energy can be classified into three distinct categories:

(1) Thermal Conversion Processes
(2) Thermochemical Conversion Processes
(3) Fermentation Processes

1. THERMAL CONVERSION PROCESSES

Complete combustion. The simplest and most direct method of recovering energy from biomass in the form of heat is by the traditional method of complete combustion--by burning in the presence of air until all of the organic material has been converted to carbon dioxide and water. The burning process can take place under a variety of conditions and in a variety of furnaces, from an open pot which is the least efficient, to a fluidized bed combustion unit (see below) which is the most efficient. Combustion begins after the residual moisture has been driven off and the temperature of the fuel has been raised to the ignition point (590°C), the temperature at which rapid decomposition of the organic matter takes place, giving rise to large volumes of gaseous decomposition and distillation products. Most of these gases are combustible but they are evolved so rapidly that a portion of them escape without being ignited. They also carry off small particles of unburned or partially burned solid material which are visible as smoke. This rapid and incomplete combustion results in a considerable loss in

efficiency. After all of the volatile materials have been removed the residual carbon burns more slowly and more efficiently.

The rate of combustion is controlled almost entirely by the amount of air available. In the open air combustion will take place rapidly and more or less completely, but these advantages are offset to some extent by the heat lost in warming the excess air to the combustion temperature. When enclosed in commercial boilers it is therefore essential to admit a minimum amount of air, and to mix it with the fuel as thoroughly as possible. Considerable waste of heat cannot therefore be avoided in an open fire, or even in a stove which is not air-tight.

The efficiency of combustion is also dependent on the size of the fuel particles and on their moisture content. For example, it is believed to be economically attractive to grind wood down to a certain size (the energy consumed in pulverizing the wood to less than this optimum size would be more than that gained from the increased combustion efficiency).

The presence of moisture in biomass fuels reduces their heating value, because extra heat is required to evaporate the free water, and also to free the bound water from the wood cells. Thus it is essential to remove as much moisture as possible prior to combustion; it is inefficient to burn biomass with a moisture content in excess of 30%. Freshly cut "green" wood and all other forms of biomass such as straw, animal dung, etc., have a high moisture content, between 20% and 80%. Drying of these materials is difficult and requires considerable time, since they rapidly re-absorb moisture from the atmosphere until they reach an equilibrium moisture content of 10-20% depending on the ambient relative humidity. This contributes greatly to transportation and storage problems, especially in tropical countries, and makes it rarely possible to obtain a moisture-free fuel from any form of biomass.

The energy value of all fuels is basically a function of their carbon and hydrogen content and may be calculated from the percentage of these two elements. Biomass materials contain a high percentage of molecular oxygen, in addition to carbon and hydrogen, whereas fossil fuels contain essentially none. The presence of oxygen in the molecule lowers its heating efficiency and thus reduces the temperature in a furnace. It should also be noted that some tropical woods contain certain chemicals which, on combustion, give rise to toxic vapors. This possibility would have to be investigated before proposing any tropical wood as fuel supply.

The system efficiency--the amount of a fuel's energy value which is converted into a usable form--is also dependent to a very large

extent on the type of combustion unit. In the rural villages of India partially-dried animal dung or wood is burnt in a type of stove known as a "chula" with an average efficiency of about 5-11% when used for cooking. Conventional Western wood-burning stoves with a controlled air supply only have an efficiency of about 12.5% when used for cooking, or about 50% when used for space heating. (A locally-produced cooking and heating stove with a simple valve controlling air intake, used for houseboats in Kashmir, reportedly operates at higher efficiency than this.) Gas burners, on the other hand, have an efficiency of about 45% when used to cook food or heat water because the flame can be controlled and it can be applied more directly to the surface which is being heated. The system efficiency of charcoal has been estimated to be 20-35%, because it burns with essentially no smoke or flame and the heat generated can be confined to a limited area.

On an industrial scale the use of wood, straw, or other forms of biomass has been restricted largely to those industries in which they are available as waste by-products. There were no major improvements in the design of the equipment used for burning solid fuels until recently, when it became more economical to use these wastes. For example, the conventional Dutch oven type of furnace is being replaced by fluidized bed units which are more efficient because of two major changes in design: 1.) The boiler is separated from the combustion chamber, so that the heat is transported by the hot combustion gases. 2.) The fuel--usually in pelletized form--combines in a more complete mixture with the optimum ratio of air, burning in suspension as the combustible gases force it into a state of permanent motion within the chamber. The efficiency of a fluidized-bed wood-waste combustion unit is claimed to be equivalent to that of an oil or gas fired boiler. Thus it is possible to estimate the value of a ton of wood waste from the cost of a thermal equivalent of fuel oil, at various price levels per gallon, as shown in Table 2.

It is apparent that direct combustion is a complex process which can vary greatly in efficiency, depending upon a number of independent factors. In the developing countries the efficiency that is obtained by burning partially dried solid fuels in an open fire is very low, even though fuel is very scarce in many areas and the labor involved in collecting the fuel represents a substantial portion of the family productivity.

Suitability of Different Biomass Fuels for Direct Combustion

Wood has been a primary fuel since man discovered fire, but it does have some undesirable characteristics. When harvested it has a moisture content of approximately 50%, and is both difficult and slow to dry. It is costly to transport because of its bulk, and it burns

TABLE 2

VALUE OF A TONNE OF WOOD WASTE AS A FUNCTION OF FUEL OIL COSTS

Moisture Content of Wood Waste	Average K cal content /Tonne	Equivalent #2 Oil	Comparable Value of one Tonne of Wood Waste 30¢ Oil*	35¢ Oil*	40¢ Oil*	45¢ Oil*	50¢ Oil*
50% Moisture 50% Dry Wood	2.23 x million	62.7 gal	18.81	21.95	25.08	28.22	31.25
30% Moisture 70% Dry Wood	3.35 x million	94.6 gal	28.38	33.11	37.84	42.57	47.30
10% Moisture 90% Dry Wood	4.46 x million	125.4 gal	37.62	43.89	50.16	56.43	62.70

*Oil costs are expressed as cents per U.S. gallon

with a long flame and considerable smoke, both of which result in a loss of combustion efficiency. Wood absorbs moisture from the surrounding atmosphere. This propensity means that it should be sheltered during storage, and even then can hardly be maintained in an oven-dry condition. The principal advantages of wood as a source of fuel are that it is socially and environmentally acceptable, it is not particularly hazardous, and it can be burnt in small and simple equipment which can even be home-made. The only by-product is a small amount of ash which has some value as a fertilizer, as it contains all of the potassium and other minerals which were present in the original wood.

Agricultural crop residues--cereal straws, husks, hulls, and stalks--all have a heating value similar to wood, and have similar advantages and disadvantages when used as a fuel by direct combustion. But the relatively higher bulk of these materials causes greater transportation and storage problems, and burning in a primitive type of stove as used in rural villages is much more difficult and less efficient than burning wood. Most of these problems could be solved by compacting or pelletizing these residues, but this requires relatively large and expensive equipment which would have to be purchased and operated on some type of community basis.

It has been reported that pelletizing only requires 2% of the energy content of the biomass, although high moisture levels may require up to 8%. Although pelletizing does improve the transportation and storage of biomass, its primary purpose is to improve the conversion technology. Pellets have a higher heat content per unit volume, are of a uniform size, which is essential for use in automatic handling equipment, and retain little of the residual moisture in the biomass.

Elephant grass and certain other grasses in developing countries appear to have potential for fuel, but insufficient information is available to determine whether the energy yield from them is high enough to be economical, or what harvesting methods should be used.

The potential yield of biomass from both fresh-water and marine plants is very great. However, the extremely high water content of many of these plants as harvested, and the difficulty in drying them in the sun, may preclude their use as a fuel by direct combustion techniques. Other methods of converting these wet crops into energy are considered to be more promising.

Animal and human wastes. India appears to be one of the few countries in which a systematic attempt has been made to determine the extent of use of non-commercial fuels. The survey indicated that 120 million tons of wood, 50 million tons of dry dung, and 30 million tons of vegetable wastes were burned each year, mostly in the villages where 80% of the population is located.

The direct combustion of dung is a very wasteful process, not only because of the inefficiency of combustion but because its nitrogen content is destroyed by burning. Phosphorous and potassium remain in the ash but are not generally recovered for fertilizer use. These losses amount to approximately 500,000 tons of nitrogen, 300,000 tons of phosphorous and 500,000 tons of potassium per annum. The alternative method of converting dung to a combustible gas and conserving all of the nutrients for subsequent use on the land is much preferred and will be discussed in a later section.

The Pyrolysis of Biomass into Charcoal and Various Combustible Liquids and Gases (Wood Distillation)

When wood or other plant biomass is heated in the absence of air it breaks down both physically and chemically into a complex mixture of liquids and gases and a residual char, commonly known as charcoal. This process is known as "pyrolysis," which can be employed either to maximize the production of charcoal, or to convert the total organic portion of the biomass into combustible liquids and gases. The latter process is usually referred to as "gasification." By comparison with the relatively slow fermentation methods of converting biomass into gaseous and liquid fuels, pyrolysis or gasification offer high reaction rates in relatively small plants, and the capability of converting a wide variety of feedstocks into a single fuel product or a variety of fuel products.

Charcoal has been produced in simple earthen pits for hundreds of years, primarily for use as a fuel because of its improved burning properties. Charcoal is comparatively easy to ignite and burns evenly with essentially no smoke or flame. This flameless combustion makes it

possible to control and utilize the heat more effectively because it is concentrated within a smaller area than is possible with wood where the flames dissipate the heat in all directions. Towards the end of the 19th century more sophisticated equipment was introduced in order to recover the methanol, acetic acid and other byproducts which were needed by other industries. Thus "wood distillation" became a thriving chemical industry until the mid 1930s when it was discovered that methanol and acetic acid could be synthesized more economically from petrochemical feedstock. However, charcoal remains a staple fuel in the small rural households in the developing world.

Unlike wood, charcoal does not absorb atmosphere moisture and therefore can be maintained in a relatively dry condition with a minimum of protective measures. The absence of any significant amounts of moisture or molecular oxygen in the charcoal is also an advantage because of their adverse effects on heating value. Charcoal has a calorific value of 7240 Kcal/kg, and a system efficiency in an open cooker of 20-35%, thus giving a net average fuel value of 1950 Kcal/kg. By comparison, air-dry wood with a moisture content of 25-30% has a calorific value of 3500 Kcal/kg and a system efficiency of 5-10%, giving an average fuel value of 260 Kcal/kg. Thus the relative superiority of charcoal as a fuel over wood is 1950/260 or approximately 7.5/1. This advantage becomes even more important as the distance between the fuel source and the point of use increases, and transportation charges become a significant factor in the overall cost of the fuel.

Wood is converted into charcoal in two stages, the "drying" stage and the "coaling" stage. The heat needed for drying and to initiate coaling is furnished by burning part of the wood. This is controlled by regulating the amount of air entering the kiln. After an initial surface zone of dry wood has been established, further heating breaks down the wood to charcoal and this process continues progressively throughout the kiln charge (i.e. the wood placed in the heated chamber).

The manufacturing process has evolved slowly over the past 200 years, from crude earthen pit kilns to modern beehive kilns which are reasonably efficient and controllable. This type of equipment works well with forestry wastes, particularly the limbs and branches of trees, but is not suited for fine agricultural wastes. The charcoal produced by these kilns is suitable for domestic consumption without briquetting or further processing. The yield of charcoal is approximately 30% of the dry weight of the wood. The briquetting of charcoal greatly improves its handling properties but adds considerably to the cost as a 10% starch binder is required.

Recent developments in charcoal production technology. The production of charcoal is of particular interest to the developing coun-

tries because of its superior fuel properties as compared with wood and other forms of biomass. In many of these countries the manufacture of charcoal is being carried out on a small scale in relatively unsophisticated equipment. This type of operation is quite labor-intensive, the yield of charcoal is poor, and there is virtually no recovery of by-products.

More recently, and especially since the energy crisis, new and improved technologies for charcoal production are being developed. For example, the New Jersey-based Nichols Engineering and Research Corporation has developed a furnace process producing charcoal and a gaseous fuel, the latter having a calorific value of approximately 1780 Kcal/m^3. This is in excess of the heating requirement for drying the wood and, if used for in-plant steam generation, is capable of producing 7500 lbs of high pressure steam per ton of wood processed. Assuming a charcoal yield of 30% by weight, the total energy recovery from the wood is about 67%, as compared with approximately 44% when only the charcoal is recovered, as in a conventional charcoal kiln.

A second process, developed by the Georgia Institute of Technology, converts a variety of crop and municipal wastes into charcoal, oil and combustible gas with 92% efficiency, although the recovery rate can fall as low as 70% when moisture levels are high. The process consists of a steady-flow continuous low-temperature pyrolysis (the actual details, including cost data, have not been disclosed). The efficiency of recovery, its viability on the relatively small scale of 50 tons per day, and its relative simplicity make the process of interest to the developing countries. It has also been reported that the equipment is portable from one location to another.

A third process, developed by Occidental Petroleum, converts municipal waste into a petroleum-type fuel oil. Since municipal waste, on an ash and moisture-free basis, consists largely of cellulosic materials, it is expected that the process should work at least equally well, if not better, on biomass feed. Finely shredded wood waste is pyrolyzed into a char, a combustible liquid, and a medium BTU gas. The gas is recycled for use as a transport medium and is eventually burned to provide heat to the pyrolysis reaction. The yield of products is shown in Table 3. Assuming that the cellulosic wastes used as feed have a calorific value of 4720 Kcal/kg, this represents an energy recovery rate of approximately 94%.

Wood distillation is a more sophisticated version of the traditional process for manufacturing charcoal in which most of the volatile products, in particular methanol and acetic acid, are recovered and sold as pure chemicals (Table 4). The synthesis of methanol and acetic acid from petrochemical feedstocks has caused the wood distillation industry in the industrialized countries to virtually

TABLE 3

YIELD OF PRODUCTS, OCCIDENTAL PETROLEUM'S FLASH PYROLYSIS PROCESS

	Calorific Value	Yield from 100 kg dry feed (kg)	Energy Recovered (kcal)
Char	4570 Kcal/kg	20	91,400
Oil	5900 Kcal/kg	40	236,000
Gas	3385 Kcal/m^3	30	119,470
Water		10	
		100 kg	446,870 Kcal

disappear. It has been suggested, however, that with the increasing prices of coal and oil over the next few years the products of wood distillation may again become competitive with chemical products from coal and oil. This situation may already exist in the developing countries where petroleum costs are higher and labor costs are lower in relation to the cost of other commodities.

TABLE 4

AVERAGE PRODUCTS AVAILABLE FROM TROPICAL WOODS
Yields per 1000 Kilograms of dry wood

Charcoal	300 kg
Gas (calorific value approximately 2500 Kcal/m^3)	140 m^3
Methyl alcohol	14 litres
Acetic acid	53 litres
Esters (mainly methyl acetate and ethyl formate)	8 litres
Acetone	3 litres
Wood oil and light tar	76 litres
Creosote oil	12 litres
Pitch	30 kg

The wood distillation process may be justified in areas which have a plentiful supply of wood but which are too far from the areas of consumption, so that the energy consumed in transporting the wood may exceed the energy content of the delivered wood. The principal products of the wood distillation process, charcoal methanol and oil, not only have a much higher calorific value than wood but also can be used much more efficiently as a fuel so that the net transportation cost per unit

of heat will be correspondingly lower. This is illustrated by Table 5.

TABLE 5

RELATIVE CALORIFIC VALUES AND EFFECTIVE CALORIFIC VALUES OF ONE TON OF WOOD AND ITS PYROLYSIS PRODUCTS

	Amounts		Calorific Value (Kcal/kg)		Calories (Kcal)	System Efficiency*	Effective Calorific Value (Kcal/kg)	Calories Delivered (Kcal)
Wood	(1000 Kg)	x	4718	=	4,718,000	11.0%	519	518,980
Principal Pyrolysis Products								
(1) Charcoal	(300 Kg)	x	7215	=	2,164,500	27.5%	1984	595,237
(2) Pyrolytic Oil	(70.4 Kg)	x	6382	=	449,292	45.0%	2140	202,181
(3) Methanol	(11.2 Kg)	x	4756	=	53,267	45.0%	2862	23,970
					2,667,059			821,388

Relative Calorific Values (Pyrolysis Products/Wood) = $\frac{2,667,069}{4,718.000} = 0.56$

Relative Delivered Calorific Values (Pyrolysis Products/Wood = $\frac{821,388}{518,980} = 1.58$

* The system efficiency of charcoal when used for cooking food has been reported to be 20-35%. An average figure of 27.5% was therefore used in this calculation. It has been assumed that methanol and pyrolytic oils can be used as effectively as natural gas when used to heat water or cook food, i.e. about 45%.

These estimates indicate that, on a weight basis (Kcal/Kg), the products of wood distillation, i.e. charcoal, methanol, and pyrolytic oils have net fuel values approximately 4 to 5 times greater than that of the original wood. This represents a savings in transportation costs of approximately 75-80%. It will therefore often be cheaper to use these pyrolysis products rather than wood when transportation costs are substantial.

The above estimates indicate that only 56% of the calorific value of the wood is recovered when it is converted into charcoal, pyrolytic oils, methanol, etc. However, because these pyrolytic products can be burnt more efficiently, the delivered calorific value is 1.58 times greater than that of the original wood. Because of this substantial gain in efficiency, it is suggested that wood distillation may provide an economic solution to the problem of providing fuel to communities which are too distant from forested areas to take advantage of the available wood. Wood distillation plants are traditionally small and labor-intensive as compared with modern chemical plants; but depending on the availability of capital, labor, and raw materials, these may be advantages in certain situations.

Wood is the most consolidated form of biomass available and is therefore best suited for the production of charcoal. Agricultural residues, and all types of terrestrial and marine plants, are similar to wood in composition and therefore will produce essentially the same decomposition products when subjected to pyrolysis. They differ markedly from wood, however, in physical form and water content, and are inferior to wood in these respects. Provided that the water content is controlled within reasonable limits they could be used for the manufacture of charcoal. The quality of the charcoal produced from these sources, however, would be adversely affected by their small particle size and low density; so it would probably be necessary to briquet the resulting charcoal--at additional cost--before it could be shipped and used.

Gasification - the Complete Conversion of Biomass into a Combustible Gas

The complete conversion of coal or wood into a combustible gas is a well-known process which has been successfully used to provide fuel for motor vehicles in many countries during periods of oil shortage. The gasification units were rather heavy (100 kg minimum) and were therefore more suitable for trucks and buses than for private cars. During 1941 the Swedish state railway operated more than 100 trains with "producer" gas from wood charcoal, and thereby demonstrated that this is a viable alternative in those countries which have to import their petroleum but have ample supplies of wood or other forms of biomass. It has been estimated that under normal running conditions 1 ton of charcoal is equivalent to 720 liters of gasoline. At a retail price of $1.00/imp. gal. this is equivalent to a value of $158.40 per ton of charcoal. During the past 4-5 years, with the oil crisis, there has been a revival of interest in the gasification of wood and municipal wastes. The current interest in this process, however, is in the production of a low or medium BTU gas for direct use as an industrial fuel; for upgrading into substitute natural gas of pipeline quality which can be fed into existing systems; or for use in the synthesis of methanol or other chemicals. A number of organizations have recently constructed or are constructing pilot plants to evaluate the production of a combustible gas.

The production of a low BTU gas. The first stage of the gasification process is similar to pyrolysis in that the wood is dried and the volatile content is removed by partial combustion or by heating, leaving behind a residue of charcoal. If the heating is continued in the presence of a limited amount of air the charcoal can be completely converted into "producer" gas, which is essentially a mixture of carbon monoxide and nitrogen. However, if at some point during this reaction water or steam is sprayed over the incandescent charcoal, then "water gas", a mixture of carbon monoxide and hydrogen, is formed.

Under operating conditions it is more practical to alternate these reactions and thus form a mixture of "producer" gas and "water" gas. The formation of both producer gas and water gas requires heat, and this heat is supplied by the complete combustion of part of the charcoal. The efficiency of gasification will not exceed about 70%, since some additional energy is required to maintain the high temperatures in the pyrolysis zone.

This dual reaction concept has been applied in a process being developed by Westwood Polygas Ltd. to produce a combustible gas with a somewhat higher BTU content. Both air and steam are used as oxidants and, as a result of the simultaneous water gas reaction, the product gas contains higher levels of CO and H_2 than conventional wood pyrolysis gas (see Table 6). Because it is very clean and free of metallic impurities, the gas has been recommended for use in a gas turbine to generate electricity.

TABLE 6

ANALYSIS OF PYROLYSIS GAS

	Westwood Polygas Process (Wood Waste) Volume (%)	Purox Process (Municipal Refuse) Volume (%)
Hydrogen	18.3	26.0
Carbon Monoxide	22.8	40.0
Carbon Dioxide	9.2	23.0
Methane	2.5	5.0
Hydrocarbons	0.9	5.0
Oxygen	0.5	0.5
Nitrogen	45.8	0.5
BTU per cu. ft.	150-170 (1335 - 1512 Kcal/m^3)	350 (3114 Kcal/m^3)

The production of a medium BTU gas. The low BTU value of pyrolysis gas is due largely to its high nitrogen content. The use of pure oxygen for combustion in place of air will result in a more combustible gas with a heating value of approximately 350 BTU per cu. ft. (Table 6.) The Purox reactor is a conventional moving bed pyrolysis unit which has been designed specifically for the recovery of heat from municipal refuse, although it could be adapted to plant biomass; oxygen is introduced near the base of the reactor and travels upflow, counter-current to the downflowing refuse. The process has been operated successfully by Union Carbide Corporation in a 5 ton/day pilot plant at Buffalo, N.Y. and a 200 ton/day demonstration plant at South Charleston, West Virginia using solid municipal waste as a feed. The efficiency of conversion was about 70-80%, the remainder of the energy being consumed in the process.

Cost/benefit ratios for the use of oxygen to produce a medium BTU pyrolysis gas from wood waste, however, do not appear to have been established at present. If the gas is to be used directly as a fuel, the additional cost of oxygen may not be practical. However, if the gas is to be upgraded into substitute natural gas for transmission in pipelines or for ultimate conversion into chemicals, it is probable that the additional cost of oxygen will be more than offset by the cost of removing the nitrogen from conventional wood pyrolysis gas.

Production of substitute natural gas. The low or medium BTU pyrolysis gases described in preceding sections can be upgraded into a high-purity methane gas of pipeline quality by a process called methanation. The crude gas from the wood gasification plant is first processed to remove water, vapor, tars, nitrogen, and carbon dioxide. The clean gas, containing primarily carbon monoxide and hydrogen, is then processed to form additional hydrogen, so that the final gas contains hydrogen and carbon monoxide in the proper ratio of 3:1. The following methanation reaction takes place in the convertor, after which the product gas must be cooled and then dried to meet the requirements of the pipeline transmission companies.

$$3H_2 + CO \longrightarrow CH_4 + H_2O + 52.69 \text{ Kcal}$$

The technology for these reactions is similar to that used in converting coal to synthetic natural gas; the cost is higher when starting from a biomass base because of the lower purity of gas from pyrolysis. Justification of the costs of raising purity (and BTU/m^3) to natural gas levels will depend on whether the synthetic is to be mixed with natural gas in pipelines, or used in equipment built for natural gas; if not, the low or medium BTU gas may be a satisfactory and clearly a cheaper fuel.

2. THERMOCHEMICAL CONVERSION PROCESSES FOR METHANOL PRODUCTION

Use of methanol as a domestic fuel. Methanol has always been regarded as an excellent fuel because it burns cleanly and can be readily transported and stored, although it has only about 50% of the calorific value of gasoline on a volume and weight basis. From an historical point of view methanol was used as a fuel during most of the eighteenth century, when it was eventually replaced by kerosene. Around 1850 it was used exclusively in Paris for cooking, heating, and lighting, because it was more economical to distill wood in the provinces and transport the alcohol to Paris than to transport the wood to Paris and then have to dispose of the ashes. This earlier and persisting use of methanol as a fuel for various domestic purposes, with no apparent problems, suggests that it may well be used again to replace kerosene in the rural communities of the developing countries.

Methanol as a motor fuel. Interest in the use of methanol and ethanol as alternative motor fuels has gone through many cycles from 1910 to the present time. As compared with gasoline, both methanol and ethanol have certain advantages which, to a very large extent, are a reflection of their physical and chemical properties. Methanol has a high heat of vaporization which results in cooler fuel mixtures and a lower temperature of combustion. These lower temperatures may cause starting problems, but they also result in lower emission levels of nitrogen oxides--compounds which are the major contributors to photochemical smog. Methanol has a much lower calorific value than gasoline, so fuel consumption will be higher on a weight or volume basis and larger gas tanks will be required. Specific energy consumption (per km), however, will be lower because of higher compression ratios and the use of simpler emission control systems. Because of its slower burning characteristics methanol is a high octane fuel, and therefore should not require the aromatic supplements which are normally added to either low-lead or lead-free gasoline for improving octane quality. Thus, even the partial use of methanol should reduce the carcinogenic risk caused by the presence of these aromatic compounds in the exhaust gases.

One potential problem with gasoline-methanol blends is the possibility of phase separation in the presence of small amounts of water. This could cause serious problems in carburetors and fuel tanks, and therefore some method of keeping water out, or some additive to dissolve it in the fuel mixture, would have to be developed. Test data by a number of organizations have indicated that up to 20% methanol can be added to the gasoline without requiring any engine modifications, but above this level some minor adjustments to the carburetor and fuel system are necessary.

Current technology for methanol production. Methanol was originally produced on a limited scale in wood distillation plants as a by-product of the production of charcoal, hence the common name "wood alcohol". During the 1920s a "synthetic" methanol was produced by passing a mixture of hydrogen and carbon monoxide over a catalyst at high temperatures and pressures. The hydrogen and carbon monoxide were produced by the reaction of steam with coke; charcoal produced from biomass would have served equally well except for its much higher cost. This process was used until the 1940s when natural gas became available in quantity; the process was then changed from using "water gas" produced from coke to "synthesis gas," produced by the reforming of methane from natural gas. This is easily the most economical and most direct process known at the present time, and all of the current production of methanol is based on the use of natural gas as a raw material.

The impending shortage of petroleum has caused experts in many countries, particularly the U.S., to advocate the use of methanol as

a partial or complete replacement of gasoline as a fuel for motor vehicles. The completion of such a program would create an enormous demand for methanol, far beyond the current resources of natural gas to supply it. Serious consideration has therefore been given to the possibility of using coal or biomass as a raw material. The gasification of coal is a relatively old and well established process which has been used in Germany and South Africa for the production of synthetic gasoline. Thus the technology for manufacturing methanol from coal is available, but so far no plants have been built because of the much higher cost of production as compared with the current process using natural gas.

Thermochemical Production of Methanol from Biomass

The technology for producing methanol by the chemical conversion of wood pyrolysis gases is similar to that used for coal, but additional processing steps are involved because the quality of the pyrolysis gas from wood is much lower than that available from coal. This is due to its high carbon dioxide content, which results from the high oxygen content of the biomass with no calorific value. However, because of the availability of forest and municipal wastes on a renewable basis, a number of organizations have studied the feasibility of producing methanol from these raw materials. The state of Maine, for example, has considered the possibility of manufacturing methanol from diseased timber stands in its large forest reserves as an answer to its energy problems. Of 12 different methods considered by the city of Seattle in the state of Washington for municipal waste disposal, only methanol and/or ammonia production were found to be profitable.

However, Prof. Thomas B. Reed of the Energy Laboratory, Massachussetts Institute of Technology, also estimated the cost of producing methanol from municipal waste, wood, and coal. His calculations indicated that the production of methanol from wood at the production level of 300 tons per day is not profitable at current prices for methanol. The U.S. Forest Products Laboratory sponsored a study of the economics of producing methanol and other chemicals from wood waste, which was carried out by Raphael Katzen Associates. They too concluded that the production of methanol was not practical, unless it was part of a large complex for producing a variety of chemicals from wood waste (Table 7).

Other studies which have been carried out recently show cost figures ranging from 28 cents per gallon to 42 cents per gallon, depending on differences in process and plant capacity. There does however appear to be a consensus that the process is not viable in North America under present conditions. It may however be viable in other countries where there are other important considerations such as a shortage of foreign exchange to buy petroleum imports. In such cases it may be desirable to use methanol produced indigenously even

TABLE 7

COST OF PRODUCTION OF METHANOL FROM NATURAL GAS, COAL AND WOOD

Feedstock	Plant Investment (million $US)	Production Cost (cents per US gallon)	Gross Profit	Net Profit	Selling Price
50 million US gal/yr capacity					
Natural gas @ $1.75/mcf	23.1	32.0	14.0	7.0	46.0
Coal @ $38/Ton	74.4	53.4	44.6	22.3	98.0
Wood Waste @ $34/oven-dry ton	64.0	59.6	38.4	19.2	98.0
200 million US gal/yr capacity					
Natural gas @ $1.75/mcf	61.0	25.8	9.2	4.6	35.0
Coal @$38/ton	178.0	41.4	26.6	13.3	78.0
Wood waste @ $34/oven-dry ton	169.0	57.8	25.2	12.6	83.0

though it costs more than imported gasoline. It is also expected that the economics of producing methanol from wood waste will become relatively more favorable in the future as the costs of coal and natural gas increase.

3. FERMENTATION PROCESSES

The conversion of all living matter by microorganisms into simpler chemicals, and ultimately into carbon dioxide and water, is a natural process which takes place during the decay of all organic matter. If this process is controlled in a digester and arrested at an opportune time, then it is possible to obtain valuable intermediate products from which can be isolated good yields of pure chemicals. When applied in this specific manner the process is known as fermentation, or bioconversion. The population of microorganisms which take part in these processes is quite large, and in some cases is quite varied, but they may be classified into two principal groups: the aerobics, which either require oxygen or can survive in its presence; and the anaerobics, which live in the absence of oxygen and may be destroyed in its presence.

Aerobic Fermentation of Biomass

Industrial alcohol. The production of industrial alcohol from starches and sugars by aerobic fermentation has been practiced for many years; but this traditional method has been replaced to a very considerable extent by the production of synthetic ethanol from petroleum-derived ethylene which, until recently, has been more

economical. In 1974, 75% of all the industrial alcohol produced in the U.S., 257 million gallons, came from this source. Apart from the more favorable economics, it has been more logical to use petroleum as a source of alcohol rather than cereal grains and molasses, that is starches and sugars, because these materials have a more important use as a source of food for both humans and animals. However, the cost gap between these two methods will diminish as the supply of petroleum dwindles and the price increases and, for these and other reasons, there will be a tendency to revert back to fermentation technology.

The demand for ethanol has remained relatively stable during the past years because its use has been restricted largely to chemical applications. However, ethanol is a very effective liquid fuel, especially for motor vehicles, and its use as even a partial replacement for gasoline would result in a greatly increased demand. It is unlikely that this demand could be entirely satisfied by using starches and sugars because they will be needed as foodstuffs. Hence there is an incentive to use wood and other cellulosic plants for the production of industrial ethanol, as these materials can be grown in areas which are not suitable for conventional farming and at a much lower cost. Cellulose, like starch, can be hydrolysed to glucose and then fermented to ethanol, but differences in the chemical structure of cellulose make it more difficult to hydrolyse to glucose either with mineral acids or with enzymes. A large amount of research has been carried out on the hydrolysis of wood with mineral acids in order to maximize the yield of glucose and obtain a by-product lignin with optimum properties for ultimate utilization. The resistance of the lignocellulose complex in the wood to hydrolysis requires the use of high temperatures and acid concentrations which cause decomposition of the resulting sugars. Thus the process must be interrupted before completion when the yield of sugar has reached its maximum value, i.e. about 50% of the weight of the cellulose. The fermentation of the resulting sugar solution to ethanol is readily accomplished in yields of 85-90%.

The process has been carried out commercially in several countries during war periods when there was a shortage of cereal grains and other foodstuffs. These plants (with the exception of those being operated in Russia) were forced to close when cereals and molasses became plentiful again because they could not compete with alcohol produced from these traditional raw materials. The current energy crisis, however, has revived interest in this process because of its excellent potential for supplying a liquid fuel, and because it does not consume raw materials which are becoming increasingly needed as food. Despite the conclusions of an earlier study commissioned by the U.S. Forest Products Laboratory that ethanol produced from wood wastes was not competitive with ethanol produced from either ethylene or grains, recent research results are more encouraging.

Researchers at the University of Toronto have been carrying out experiments on the production of ethanol, methanol, and other chemicals from aspen wood. Their tentative conclusion is that ethanol can be produced more economically than methanol from wood, and that relatively small plants, of 60-120 tons per day, may be economically viable. If this conclusion can be verified, the process may have application in the developing countries.

Production of ethanol from sugarcane. Most of the advantages and disadvantages which pertain to the use of methanol as a motor fuel also apply to ethanol. It has a lower calorific value than gasoline, but since an ethanol engine ideally operates at a higher compression ratio and delivers 18% more power per liter than gasoline, the two factors effectively cancel one another. Ethanol may, however, give slightly better mileage because an alcohol engine can be tuned to run on a much leaner mixture than a gasoline engine. It also does have a marked advantage in eliminating the use of lead anti-knock compounds and in reducing the amount of hydrocarbon and nitrogen oxide emissions. From a toxicological point of view ethanol is considered to be much less toxic than methanol. Workers have been exposed to relatively high concentrations of ethanol fumes without any apparent serious long-term effects. Cane sugar is an excellent raw material for the manufacture of ethanol and yields of about 50% based on the weight of dry sugar can be realized. E. S. Lipinsky of the Battelle Columbus Laboratories concluded that ethanol produced from sugarcane could be competitive with ethanol from other sources if some credit is allowed for the fermentation residue which has a high protein content and is normally used as a cattle food (Table 8).

TABLE 8

COST OF ETHANOL FROM SUGARCANE JUICE

	$/gallon (US)
Sugarcane juice	0.81
Operating Costs	0.32
Annualized capital charge	0.22
Stillage byproduct credit	(0.19)
Net cost per gallon	1.16

This study is based on U.S. economic conditions in 1978, which are liable to change rapidly as petroleum prices continue to increase.

Cassava is being considered as a potential raw material for the production of ethanol in Brazil. The yield of alcohol from cassava is about 165-180 liters per ton which, on a weight basis, is much higher than that from sugarcane. However, since sugarcane has a much higher yield per hectare, the alcohol yield per hectare of sugarcane is also higher. The basic reason for considering cassava is that it is easy to

grow and unlike sugarcane it can be cultivated on otherwise unused land. Sugarcane, on the other hand, can only be grown in a few parts of Brazil much of which is already under cultivation, so that a greatly expanded ethanol production will require other raw materials as well as sugarcane.

The cost of producing ethanol from cassava has been estimated by McCann and Saddler, who have considered the possibility of growing it in Northern Australia as the raw material for the production of a variety of food products as well as ethanol. On the basis of their estimates, ethanol could be produced at a cost of $0.65 per gallon at a minimum production level of 200,000 tons per year. This cost includes a 25% return before tax, and it therefore was concluded that it would be economically viable to produce ethanol from cassava for use in ethanol-gasoline blends.

Anaerobic Fermentation

The formation of methane and carbon dioxide by the anaerobic digestion of animal and vegetable matter was first reported in the late 19th century. It is now believed that the process is part of the mechanism by which some of the large deposits of fossil fuels were formed in the earth's crust. The mixture of gases which is produced is highly combustible and has been commonly designated as "biogas". It consists essentially of about 2/3 methane and 1/3 carbon dioxide, but it also contains moisture and minor amounts of hydrogen, nitrogen, organic sulphides, and higher hydrocarbons. The crude gas may be used directly for heating and lighting applications, but it cannot be piped any distance without first removing the moisture and the carbon dioxide.

During the past 50 years many cities in Europe and North America have built anaerobic digesters to treat their sewage and in many cases have used the gas as a source of fuel for this operation. Any excess gas, which often accumulates during the summer months, is generally piped into the municipal gas system. In India, the construction of small biogas plants by individual families was initiated in 1951, in an effort to convert cow dung into a cleaner, more convenient fuel rather than burning it directly. Progress was slow until the mid-seventies when the fuel crisis stimulated the Government to provide additional technical and financial support. In 1976 there were over 36,000 biogas units in operation in India and the Government has a target of 100,000 by 1978. Most of these units are on an individual family scale and are reported to produce only enough gas during part of the year for their immediate needs, which are mostly cooking (99.5%) with a small percentage used for lighting (0.5%). There are, however, a few larger units operated by cooperatives, government, or industry, in which part of the gas is used as a fuel for small engines to generate power or electricity.

The largest number of biogas installations is in China, where more than 2,800,000 peasant families in the province of Szechuan were producing their own biogas by the beginning of August 1976. The Chinese design is of interest because it is constructed of brick and cement and has no moving parts. The digester has two compartments, one of which acts as a storage tank for the liquid slurry when it is forced from the digestion chamber by the formation of gas. The average capacity is about $10m^3$ and this is capable of generating $5m^3$ of gas per day which is sufficient to meet the lighting and cooking needs of 5 persons. The gas is also used for driving small internal combustion engines. The Chinese report that there is a 90% reduction in disease-causing organisms due to the long retention time under unfavorable growth conditions at the bottom of the tank.

In addition to these developments it is also reported that there are 27,000 biogas installations in Korea, 7,500 in Taiwan, and much smaller numbers in Pakistan, Nepal, Bangladesh, the Philippines, Thailand, Indonesia and Japan. In some of these countries, where the availability of firewood is not a problem, the anaerobic digesters are used for sanitation and environmental control. Japan, for example, has carried out considerable work on the treatment of industrial and urban wastes as well as livestock wastes from the point of view of pollution control. It is the only country which has adopted a high temperature digestion process (53-54°C). Japan claims that high-temperature digestion makes it possible to increase the digester loading by a factor of 2.5 while reducing the retention time to 5-7 days. However, the process is a much more sophisticated operation which requires heat exchangers, insulation, and much better supervision. For this reason it does not appear to be suitable for any but very large units.

In the industrialized countries there is also increased interest in anaerobic digestion, not only of sewage but also of animal and vegetable wastes for the purposes of recovering fuel, feed, and fertilizer values. Most of the work in the U.S. is being carried out on a pilot scale by universities or agricultural research organizations under the sponsorship of the Department of Energy.

Operating considerations. Biological reactions are very sensitive to shocks such as rapid fluctuations in temperature, acidity levels, rate of feed addition, and others, and are therefore much more difficult to operate on a steady basis than chemical reactions. This makes it rather difficult for a farmer to obtain a steady supply of fuel from his biogas unit which is subject to all the variables of the weather and to the lack of uniformity of the feed material. As an example, it is not practicable to heat digesters in some areas during winter months since the energy required would amount to a large proportion of that produced. The only solution is to conserve as much as possible by adequate insulation.

The economics of biogas units. The conventional practice of burning dried animal dung in an open fire is very inefficient, as only about 5-11% of the heat is used effectively, the remainder being dispersed as an acrid smoke which is injurious to the eyes. In contrast it has been estimated that 50% of the energy available in the original cow dung can be converted into biogas and, if this biogas is burnt in a specifically designed cooker, a conversion efficiency of 60% can be obtained, for an overall recovery rate of 30%. If a conventional cooker is used the conversion efficiency is only 35% and the overall recovery will be reduced to 21%, which is still about twice the amount of heat available from burning dung in an open fire. A comparison of the relative efficiency of biogas with other fuels is shown in Table 9.

TABLE 9

RELATIVE FUEL VALUE OF BIOGAS AND OTHER MAJOR FUELS

Fuels	Fuel Heating Value	
Coal (town) gas	4,000-4,445	Kcal/m^3
Biogas	4,800-6,225	"
Methane gas	7,965-9,500	"
Acetylene gas	13,335-14,225	"
Propane gas	19,460-23,115	"
Butane gas	25,780-30,225	"
Animal dung	2,127	Kcal/kg
Soft coke	6,200-6,600	"
Coal	7,550	"
Charcoal	6,950-7,750	"
Fire wood	3,885-4,700	"
Kerosene	10,800	"
Furnace oil	10,800	"
Ethanol	7,120	"
Methanol	5,340	"
Electricity	860	Kcal/Kwh

A number of studies have been carried out on the economics of operating biogas plants on an individual family scale. M. S. Swaminathan has used three different criteria for estimating the value of the biogas, i.e.:

(a) The cost of a thermal equivalent of kerosene.
(b) The cost of generating 1 cu. ft. of biogas.
(c) The cost of the quantity of kerosene which is thermally equivalent to the quantity of dung required to produce 1 cu. ft. of biogas.

His calculations indicate that for a small 2.83 m^3/day unit the value of the biogas produced, i.e. 0.0186 rupees (R), is somewhat less

than the sum of the value of the raw material and the cost of production (0.009 R plus 0.0155 R = 0.0245 R). This calculation, however, does not make any allowance for the value of the sludge as a fertilizer, which should be considerably more than the 0.0059 R difference between the value of the biogas and the total cost of production. In another calculation Swaminathan has estimated that the increase in fertilizer value obtained by not burning any of the dung as a fuel is considerably greater than the total cost of producing the biogas. He therefore concluded that, from an individual farmer's point of view, the cow dung biogas plant is an economically viable proposition.

Advantages of anaerobic fermentation of animal and vegetable wastes (as noted in India):

(a) Biogas is a very convenient fuel with a high overall efficiency as shown in Table 9.

(b) The use of biogas provides a much cleaner, healthier environment in the home and reduces the incidence of eye diseases caused by the smoke from the traditional burning of solid wastes.

(c) The fertilizer value of the waste, which is lost if the fuel is burned, is retained with the possible exception of a loss of about 10% of the nitrogen if the residual sludge is dried. This results in a substantial saving in foreign exchange.

(d) Anaerobic fermentation is superior to composting because it permits the recovery of 50% of the fuel value. This results in a saving in forest land through less dependence on firewood, estimated to be 0.3 acre for each 100 cu. ft/day (2.83 m^3/day) biogas plant.

(e) The process can be operated on almost any type of organic waste with solid contents up to 10%, and even on soluble materials. Using direct combustion techniques it is not generally practicable to recover heat from wet fuels if the moisture content cannot be reduced below 60-70%.

(f) The equipment required for anaerobic digestion is relatively simple and can be made from readily available materials as the process is operated at ambient temperature and pressure.

(g) A medium or high BTU gas may be obtained, depending on the transportation and end use requirements.

(h) The process has a favorable environmental impact because it reduces smoke and improves sanitation in the villages.

Disadvantages of anaerobic fermentation of animal and vegetable wastes:

(a) The principal disadvantage of the biogas process is the relatively slow rate of anaerobic fermentation as compared with thermal methods of gasification. Fermentation time can be reduced from 100 days to approximately 7 days by increasing the temperature from 35°C to 54°C, but the additional energy required may only be feasible in large-scale units.

(b) The process may not completely destroy all of the pathogenic organisms which may be present; and some type of post-treatment of the sludge is desirable or necessary to remove this potential hazard. Of course this hazard is greater with the original material.

(c) Biogas, when mixed with air in certain proportions, forms an explosive mixture which could be quite dangerous.

(d) A scum normally forms on the survace of the slurry in the digester and this has to be disturbed at regular intervals to maintain biological activity.

Potential of anaerobic fermentation of animal and vegetable wastes. It is apparent that anaerobic fermentation of animal and vegetable wastes to produce biogas has considerable potential which is only being utilized to a minimum extent at the present time. An approximate estimate of the quantity of fuel and fertilizer which could be recovered from all of the available human and animal wastes in the South Gujarat Region of India is shown in Table 10.

TABLE 10

POTENTIALITIES OF BIOGAS PLANTS (PER ANNUM) SOUTH GUJARAT

		Case I	Case II
		When only installed plants in the region are considered	When available yield from both the cattle and human wastes of the region are considered
1.	Biogas	4.93 million m^3	366.0 million m^3
2.	Kerosene equivalent of available gas	3.20 million liters	238.0 million liters
3.	Electrical energy equivalent of available gas	26.0 million Kwh	2136.0 million kwh
4.	Manure	40,000 tons	2.10 million tons
5.	Nigrogen content in the manure	600.0 tons	31,500.0 tons

These estimates indicate that less than 1.5% of the total human and animal waste available is being utilized for the production of biogas. Some of the reasons which have been given for the slow adoption of biogas plants are as follows:

(a) High installation costs.
(b) Low productivity during winter months when the fuel is needed most.
(c) Corrosion of gas holder.
(d) Necessity of owning cattle.
(e) Lack of suitable extension and maintenance service.
(f) Lack of land in the village for disposal of the slurry.
(g) Social prejudice against acceptance of dung--night soil gas plants.
(h) Lack of alternative sources of fuel for villagers who do not own any cattle.

Anaerobic fermentation of aquatic plants and wet agricultural wastes appears to be a most appropriate technology for the processing of biomass into fuel, fertilizer and feed. Water-weeds thrive on sewage, they clean the water effectively and grow rapidly in the process. Thus they may serve a dual role of improving the environment and providing a significant source of energy.

An economic assessment of the production of biogas from water hyacinth has been carried out by Lecuyer and Martin. Water hyacinths were selected as a feedstock because of their prolific growth rate and because they are floating plants which can be easily harvested. The biogas was upgraded from 5340 Kcal/m^3 to 8900 Kcal/m^3 (pipeline quality) by absorption of the carbon dioxide in hot potassium carbonate solution. It was concluded that the process is ecologically sound, technically feasible, and almost economically viable at current prices for natural gas. It was suggested that if any reasonable value could be assigned to the residue the process would be economically feasible at the present time. The only serious objections to this process are the large amounts of land and water required.

[Adapted from a section of the report of the International Development Research Center, Energy from Biomass for Developing Countries: A state of the Art Report, IRDC - MR3, Ottawa, Canada, February 1979. Published with the permission of the International Development Research Center.]

BASIC NEEDS POLICY

Some of the major features of basic needs development programs are illustrated overleaf. From upper left clockwise they are: a school-age children's nutrition program in Indonesia (Photo: U.S. AID); a Bolivian public health clinic (Photo: U.S. AID); a literacy class in Mali (Photo: World Bank); rural housing in Ecuador (Photo: Food and Agriculture Organization).

National Policy Implications of the Basic Needs Model

Soedjatmoko

[The development model stressing the meeting of basic needs of all people in a nation has received increasing attention as a goal, but too little in its policy implications for effective action. This article first reviews the policy implications in major sectors, then explores these implications in such fields as culture, communications, research, administration, and political organization.]

We all know that the "basic human needs" approach to development grew out of the search for a development strategy which could deal more effectively with the problem of continuing poverty in large parts of the world. It has been envisaged that such a strategy should, within a period of 25-30 years, be able to reverse the trend of growing inequality in developing societies which threatens to leave the poorest 20% of world population permanently in conditions of absolute poverty. The basic needs approach constitutes a direct attack on world poverty by giving first priority to meeting the basic needs of all people in a society for food, clothing, health, education and housing, and by stressing employment and income generating activities among the lowest 40% income groups. As formulated in 1976 by the International Labor Office (see Development Digest of January 1977, p. 32), it is predicated on a policy package consisting of relatively high national growth rates (6-8%), redistribution of income and--up to a point--wealth, reorientation of investment, and a review of consumption and production patterns. It is hoped by its supporters that such a thrust will lead to processes of internally generated development, which over time might develop into an indigenous engine of growth.

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It is no wonder that the Basic Needs Model has in a relatively short time gained much popularity, and has even become fashionable in many quarters of the international community. In a way deservedly so. The Basic Needs Model is undoubtedly an important contribution to development theory with great moral appeal. It provides a promising point of entry into a development problem which seemed beyond the effective reach of earlier strategies. It has, in fact, already led to important adjustments of existing development programs in various countries. Nevertheless, it is also true that, while important work has been done in developing data in support of the concept as well as policy packages in some priority areas, surprisingly little has been done to study the national policy framework which the Basic Needs Model requires for effective implementation. Several studies mention the need for "political will" as a prerequisite for the implementation of the model; but all remain silent on how to generate such a will. Nor do they consider the political risks and costs involved, the difficult economic and political trade-offs that have to be made, and other perplexing dilemmas that have to be faced in this connection.

This paper is a tentative and necessarily subjective effort to look at some of the broader domestic, as well as international implications of the Basic Needs Model for national policy. It raises the question of the capacity of political systems to absorb the requirements of the model; of the nature of social change, and of the development process which constitutes the environment within which the Basic Needs Model has to be implemented; and of the ideological presuppositions which bear on the choice of methods of meeting basic needs.

One point should be made at the outset. Although it is often presented in a very programmatic fashion, the Basic Needs Model takes us into a number of areas about which, collectively, we really know very little. We still don't know for instance, despite some success stories, how to bring about rural development. We know little about how to stimulate small business enterprises in rural areas or in urban informal sectors. We don't know very much about the income- and employment-generating linkages in the rural areas, and even less about how these are affected, directly or through different technology choices, by fluctuations in food prices. While we know something about the macro picture of production, consumption and import gaps for food, we know rather little about food consumption patterns broken down by income groups; this would give us important clues as to which differential food price policies would be most likely to maintain and improve the calorie-protein intake of the poorest 20% in both rural and urban areas in the face of higher costs for the main staple food. The policy choices that would have to be considered require a data base which is still quite inadequate in many countries, and can only be developed slowly. In short, a great deal more research and analysis will have to be done before it becomes possible to postulate, with some degree of confidence, the policies and programs which the Basic Needs Model realistically requires.

Defining Basic Needs Problems

In considering focal areas of the Basic Needs Model and the local and national policies they require, it should be noted that, while there is considerable consensus about the general direction of such policies, there is much less certainty about how such policies should or could be implemented. In order to explore the policy requirements involved, it will first be necessary to define briefly some of the implementation problems and methods that seem to be implied in the Model.

Food, nutrition and employment. Although there have been spectacular increases in food production in some countries with the new technologies of the Green Revolution, there are many developing countries where food production growth rates seem to be starting to taper off. In some cases the slack in existing systems is being taken up; there are also institutional constraints that are increasingly showing themselves to stand in the way of further rapid increases. The expansion of tertiary irrigation networks is one example of a necessary development that is often held up by existing land ownership patterns, and full utilization of potential water resources is sometimes checked by problems of water control. Land reform and improved land tenure practices should aim at the establishment of higher yielding farm systems through group and cooperative organization. Such improved farming systems should develop a broader range of foodcrops, supported by policies aimed at stabilizing food supply, and price policies for the various foodcrops which will ensure higher production without reducing, but rather improving, the nutritional value of food consumed by the rural landless and urban poor. Unless social relations in the rural area are democratized, using national policies and legislation but especially through developing locally effective organization of the small farmers, the traditional hierarchical structures will continue to exercise important constraints on initiative and productivity.

These are a few of the many problems of getting more food produced, and getting it to all a nation's consumers. Some others would be the following: while price increases for the major foods can provide a stimulus to production, their effect on the incomes of the small farmers and landless laborers may be less positive than for the large farmers. Even when increased incomes derived from higher food prices do enable the rural poor to pay more for their food, the larger farmers might at the same time decide to go in for more labor saving technology to maximize their profits, and this can displace tenants or landless workers from the production process. Policies aimed at the small farmer, and where possible at the group of landless labor, should include support and incentives for intensive home garden cultivation, small animal husbandry, trees for firewood, and fishponds, all of which could help in providing additional income and could improve the nutritional value of the diet.

Labor-intensive public works projects and the stimulation of rural, non-agricultural small business, needed in any case for expansion of food output, might provide the additional income which could compensate for possible adverse effects of increasing output on the income of the poorest groups and the presently unemployed. The building of local infrastructure, roads, tertiary and quaternary irrigation canals, terracing hillslopes, reforestation, in ways which simultaneously take care of the food production--and energy--needs of small farmers and landless labor, could be organized in such a way that these would provide additional income for those groups, while improving the carrying capacity of the environment. In important parts of many countries, the combination of poverty and overpopulation has already seriously upset the ecological balance between man and nature. In those areas there is no prospect of supplying food for the doubled population which has to be expected in the next 25-30 years unless erosion and large scale deterioration of the natural environment are halted, and policies of massive rehabilitation and improvement of the environment are carried out. The magnitude of the effort required, as well as its great urgency, provide an opportunity to increase incomes of a number of landless workers and smaller farmers.

In general, special efforts need to be made for the agricultural infrastructure of supporting services, like extension and credit facilities, to reach the two target groups of small farmers and landless labor; the institutional constraints standing in the way of their access to processing, distribution and marketing facilities, and their access to relevant information, technology and training, should be removed. In addition, these two target groups should be assured of increasing participation and control, as their own organizational and management capabilities grow through the stimulation of community and functional organizations. This raises the question whether, ultimately, effective decentralization and a considerable devolution of power to the lowest possible level of an administrative hierarchy, where concentration of domestic technical assistance capabilities in various fields should also be located, might not be an essential condition for increasing rural productivity, and thus for the effective implementation of the Basic Needs Model. The difficulties encountered in past experience at this level point to limits in the capacity of centralized administrative systems in meeting the basic needs of the poorest 20%. But the development of organizational and managerial capability at local rural levels is at best a slow and uneven process. It is obvious that the program implementation will inevitably have to be experimental in nature in its early stages, and will have to be continuously monitored and evaluated. But most important is the adoption at the national level of such policy objectives in the overall development strategy.

Health. Even in countries which have committed themselves to expanding health care, it has become obvious that it will be impos-

sible to provide conventional health services that could reach the poorest 20%. This is true even in cases where a significant reallocation of the total health funds toward rural facilities has already taken place. The operative radius of health clinics may not be more than between 5 or 10 kilometers, i.e. the distance a patient could cover on foot. Cost, and shortages of trained medical, technical and other para-medical personnel are the major constraints. And in poor developing countries with a large and growing population, the building of new facilities must be enough to keep up with population increase. Further, the Basis Needs Model emphasizes environmental health and community protective health care. It is assumed that the provision of safe water and sanitation would significantly reduce the impact of waterborne diseases which, coupled with immunization, would improve the general state of health of the poorest and their life expectancy, especially of children.

It will be necessary to reorient medical education to the needs of the poorer 40%, while at the same time medical schools should be able to keep up with recent advances in the various fields to serve the modern sector and to have the capability of adapting new scientific breakthroughs which can improve mass health care. These two conflicting pulls are not easily reconciled. On top of this, there is the need to inculcate a medical ethos among the young doctors to work and live among, and for, the urban and rural poor; obligatory national service in community health care, as initiated by various countries, is one step.

Housing. The emphasis on self help in the building and improvement of housing is the most promising solution for the poor in developing countries with a large population. It will require credit facilities on the ground for building whole houses or parts of the house (core-house or roof), the development of building associations or cooperatives, the stimulation of local consumption and the use of local materials by firms manufacturing building materials, and site-and-services preparation in urban areas. In many cases rural areas are devoid of the legal conditions necessary to use the available credits because of uncertainty of land titles, incapacity to provide required collateral, or legal incapacity to enter into mortgage commitments. An effective housing program that could meet the demand created by population doubling in the next 20-25 years will require laws that could provide, in various forms, a security of tenure which would give individual citizens a sense of continuity and self-help incentives. It will also require area development policies which could help to establish intermediate sized towns and rural settlements that would strengthen agriculture, and lessen the pressure on the big cities. As a result of population growth, many villages will become small towns and many small towns will become big towns; this will require policies governing the resulting shifts in land use and settlement planning.

Education. A basic needs approach to education requires an emphasis on functional literacy for all which, as formal schools are incapable of supplying it, will have to be achieved through various forms of non-formal education. Here, the minimum learning package developed by UNICEF might be of great significance, as would be efforts to integrate the literacy effort into other programs aimed at meeting basic needs. This calls for functional literacy efforts in the workplace, in the family, and the community, with or without the help of ambulant teachers. The next priority will have to be on basic education, the attainment of universal education--if not for the whole duration of primary school then at least for a period of 3 years. Basic education to meet basic needs will require considerable educational reform, covering both school curriculum reform and teacher training, in order to harmonize the educational system with the social environment, as well as with the development requirements of the community and region. This implies a reorientation of higher and secondary education to the problems of the rural areas, and to develop the higher as well as para-academic skills necessary to support this effort. University involvement in development research, planning and evaluation are obvious steps towards developing, among the universities and their students, a sense of social solidarity with and a commitment to serve the poor majority of their population. But the process of reconciling this with the growing needs of the modern sector and the need for academic quality is bound to be long and difficult.

National Policy Implications

The Basic Needs Model requires an appropriate macro policy framework for development. This should include the adoption of employment and equity as development goals of equal importance with growth. It also means the determination of certain specified production growth goals, and a commitment to development from the bottom up, to local self-reliance, community and grassroots organization and participation in planning, decision making and implementation in areas affecting those communities. A reallocation of total investment is implied, especially of national funds for health, education and housing, in favor of the lowest 40% income group. Some further requirements would include: 1.) land reform, including where necessary the provision of land for home garden cultivation for each household; 2.) abandonment of price policies for food stuffs which traditionally tend to favor the urban population, and adoption of policies favoring the rural areas in a manner which stimulates food production and increases rural income; 3.) changing the terms of trade between the urban and rural sectors, which traditionally worked to the benefit of the cities, through realignment of taxes, import and export duties, and exchange rates; 4.) progressive taxation on a broader tax basis, and reduction of differences in consumption patterns between the modern and the rural sectors; 5.) Industrial policies giving priority to labor-intensive in-

dustries and labor-intensive production processes that are compatible with the requirement of efficiency, and policies favoring industries serving small rural enterprises; 6.) Human settlement and area development policies, as noted earlier. In addition, changes in a number of more general policy aspects are called for.

Communications policy. The effort to meet basic needs will obviously require an unprecedented inflow of information into the villages, capable of reaching the poorest villagers as well as the local gentry. This will be necessary to develop programs to increase agricultural productivity, stimulate and guide adjustment to new methods of food production, new crops, new methods of improving livestock, and to provide access to relevant market information to make possible utilization of new opportunities in trade and rural manufacturing. Also needed are programs which increase the farmer's understanding of his utter dependency on the environment, and his urgent responsibility for maintaining and improving its quality.

It is unlikely that the amount of information a farmer would need to adjust to social change and opportunities could effectively be transmitted through the traditional channels of communication: the village headman, the extension services, and the educational system. What is essentially called for is the transformation of the village from a traditional society to an "information community," capable of acting and responding creatively to relevant information reaching it and also of reaching out for that information. Apart from village level wall-newspapers or newssheets for the tenants, the communications breakthrough that is needed may well require specially designed programs on TV, radio and cassettes directed at the villagers, and at the same time responsive to their wishes and needs. Central programs will of course have to be developed, as well as their proper reinforcement mechanisms in the village, but always in combination with locally or regionally designed programs in which the community directly concerned could participate (in the demonstration of results, exchange of experience, discussions).

The location of the public village TV set, in countries where this is available, should be such that the programs are fully accessible to all during the whole broadcasting period even to the poorest members of the village. This also holds for the village public telephone whenever available. Program packages that are comprehensible only to the better educated villager would work to the relative disadvantage of the lower-income, less educated groups and would only widen the income gap. Inasmuch as the basic needs approach aims at improving the opportunities for the rural (and urban) poor, and requires for the successful implementation of its programs community and group action, the information flow into the village should also include specific information regarding the rights of each villager,

inherent in each program. He also needs specific information as to where and how to obtain legal redress for real or perceived injustice done to him.

Quite useful volunteer schemes for rural development have operated in a number of developing countries with generally encouraging results, but in only a very few cases have such volunteers been given a mandate actively to promote the interests of the villagers themselves. It would seem that an expansion of the latter role of informing the villagers of their rights in such programs, and helping them to secure those rights if and when necessary, would be highly desirable. This could conceivably be done through summer programs for high school volunteers as well as through university study-service programs. But even under the best of circumstances, the communication problem in rural development is a formidable one. There is often a wide gap between the felt needs and aspirations of villagers and the assessments of local priorities on the part of administrators and planners at higher administrative levels. The basic needs approach calls for new or improved mechanisms for dialogue and interaction--in short, for mutual education, and above all, on the part of planners and administrators, a greater capacity and willingness to listen respectfully.

Cultural policies. The efforts to meet basic needs may not have an appreciable impact on slowing down the movement towards the cities unless simultaneously the overall quality of life within the villages is improved. Some aspects of this could be attained through village access to, and participation in, cultural activities at the local, regional and national level. If TV is not to be an instrument which only increases the impulse to migrate to the cities, it will have to be "domesticated" to serve the needs for cultural participation in the village. Decentralization of programming would open the way for locally produced programs which could stimulate local cultural activity and creativity, and a community's capacity for cultural self enjoyment. It would also halt the long process of gradual cultural impoverishment that has afflicted village life in many developing societies, in part as a result of overly urban-oriented modern education, but for other reasons as well. Decentralized programming, linked for instance to village competitions in music, theater, dance, literature, sports, children's games and folklore, painting, sculpture, wood-carving and other crafts, would be an important means of combating the passivity that usually characterizes TV audiences. Such cultural activities would also preserve cultural continuity, so necessary for reducing the growing disorientation and alienation of the young from the cultural and spiritual values of their community.

On a more essential plane, it is impossible to overestimate the difficulties in helping to stimulate and nurture the kind of attitudinal

changes which are needed to enable villagers to break out of the traditional hierarchical social structures which have for so long imprisoned them. Changes in the local distribution of power, i.e. democratization, is of course, one important precondition. Still, many of those attitudes, of the rich and the poor alike, are rooted in trancendental preconceptions of the social order. Individualization, personal self-reliance and initiative, the stimulation of notions regarding the possibility and legitimacy of trying to improve one's material conditions and those of one's family, are important elements on the road to emancipation. And cultural policies aimed at stimulating those qualities and values have great developmental significance. But on the other hand, given the need for community action in a labor-intensive type of rural development which the basic needs approach implies, as well as the high degree of population density that can be expected in the next 30 years in many areas as the population doubles, cultural policies will be needed which at the same time stimulate contrary values. Some of these would be: a greater capacity for cooperation rather than individual competition, a greater sense of social solidarity, an emphasis on mutual obligations rather than on individual rights, and an acceptance of voluntary individual self-restraint for higher collective goals. Many of these values are part of the traditional value and belief systems--although it should also be noted that in many cases these values have been eroded by growing inequality in the local distribution of power to the point where procedures of mutual help and local consensual decision-making have been turned into vehicles for exploitation by the locally powerful.

The basic needs approach, and in general the concept of development from the bottom up, sharpens these value conflicts and turns the conciliation of these contradictory requirements for cultural policy into a new imperative. It is obvious that each country and each culture will have to respond in its own way to this challenge of harmonizing continuity with change through creative adjustment and imaginative innovation. Cultural policies in transitional societies, especially in Asia, should not overlook the role that religion has played in shaping social organization. It has shaped people's perception of the meaning of life, and of their relationships to their fellow human beings, to society, to nature as well as to the transcendental. It still constitutes a powerful source of moral validation, and of motivation for individual and social action. Cultural policies in support of the basic needs approach in an environment of social transformation, with its uncertain and shifting value configurations, might therefore well find in the prevailing religions potentially powerful forces for constantly needed reintegration.

Research and technology policies. All basic needs programs will have to have a built-in research component that will make possible

continuous monitoring and evaluation, adjustment and innovation--for reasons given earlier. In many developing countries, however, the growth of research capability has not matched the expansion in the use of new technologies. For example, a national research policy supporting the basic needs approach will have to include research and development aimed at bringing indigenous technology, including agricultural implements, up the next step of the technological ladder but without taking the improved product out of the reach of the small farmers. Research should also include the adaptation of more sophisticated types of technology in cases where the results would be beneficial to the poorest part of the population. Beyond this, in light of the growing awareness that certain types of research produce knowledge or technology which tend to be more useful to the rich and other types which favor the poor, developing countries will have to direct a larger part of their research capabilities to those problems that are especially important to the poorest part of the population, or which are at least neutral in their social impact.

Some basic services (health, education) are now using a technology that is still too expensive to reach the poorest among the rural, as well as urban population. New, cheaper technologies will have to be developed that are replicable on a large scale. In addition, research relevant to the development of non-agricultural small enterprises in the rural areas is another high priority research area. Special attention should also be given to the development of another type of research and analytical capability: considering the extremely difficult policy mix and the gaps in our knowledge and understanding of the complex processes of rural dynamics, it is extremely important for a country committed to the basic needs approach to be able to make periodic assessments of policy results. A country must be able to analyze where it has gotten in pursuing its course within shifting limits of the possible, where things are going, and whether it should pursue or adjust its policy mix. Basic-needs-connected research may require different institutions at various levels. They all require interdisciplinary work, with different disciplinary mixes; but all should include a much heavier participation of social scientists, in light of the need to orient technology to serve social goals. The development of such research capabilities must include an expanded training component, whatever the present scope.

Energy policies. The Basic Needs Model raises questions about the supply and materials of energy available to the poor, and the requirements for the chosen directions of technological development; solutions will have to be integrated into a national energy policy. Rural development will require increased energy use for irrigation, fertilizers, draft power for cultivating the land, as well as small machines for agricultural processing; for small scale manufacturing;

and of course for cooking and heating. While in some areas rural electrification may be the answer, in poor areas that are isolated, or have a widely dispersed population, the development of alternative energy resources is an absolute necessity. For a considerable period firewood is bound to remain the major energy resource of the poor, and this will require the development of programs towards its more efficient use. In all these areas, vital linkages will have to be made with research and development abroad, especially with those concerned with the soft technologies in energy.

Administration policies. Before the advent of the basic needs concept, it was normally the bureaucratic machinery which was considered the main instrument for implementation of development plans, and for the mobilization and guidance of the population in the development effort. But the Basic Needs Model, with its emphasis on development from the bottom up, community participation and initiative, autonomy and village self-reliance, puts a premium on the development of local organizational and management capacity in rural communities. It means, in short, the adjustment of traditional hierarchical and patron-client relationships to more modern, more democratic forms of social organization, capable of addressing new problems.

All this runs directly counter to the conventional bureaucratic approach to the village, which tended to strengthen traditional structures. It means, in effect, a quantum jump from paternalism to emancipation, requiring fundamental changes in attitudes on the part of the administrators, and in the prevailing, deeply rooted concepts of the proper relationships between the governing and the governed. The transition will not be an easy one. Any central bureaucracy tends to overlook the inherent limits to its role as the paramount instrument of development: at some point in the development process, initiative and responsibility of farmers and rural communities become essential conditions for further progress. Further, no such bureaucracy is capable of policing itself effectively in the absence of countervailing social forces from outside itself. Despite all good intentions from the top, particular policies will inevitably be twisted because of pre-existing cultural and administrative patterns and the interplay of interests, reducing the effective implementation of central policies as intended.

Another source for difficulty in bringing about this transition is the unavoidable drop in efficiency resulting from the handling of particular developmental tasks by inexperienced organizations and people. The absolute necessity that these young institutions be given the opportunity to make their own mistakes is likely to be considered a waste of time. Still, it is only in freedom that these institutions can learn, can develop the skills and also the self-confidence and self-discipline that are essential to their further

development. It is therefore likely that only a firmly committed government, capable of maintaining continuous pressure on its bureaucracy, will be able to bring about such a transition.

The Basic Needs Model also calls for adjustment in the training and education of public administrators. The earlier attitude of educators towards public administration as a sanitized, insulated, technocratic enterprise, should be replaced by an understanding of how public administration is inextricably part of a whole network of social interactions. This would mean understanding how differently policies look when they come out of the bottom of the mill at the village level from the way they seemed when initially formulated, and why. Just as important as effectiveness and efficiency in public administration is an understanding of the pitfalls that face an administrator in the implementation of given policies.

Legal policies. Land reform constitutes, in itself, a major piece of legislative work. The land reform law will have to cover adequate monitoring mechanisms and procedures for protection of the small farmers as well. Furthermore, the establishment and proper functioning of cooperatives and other rural associations, of rural credit institutions, of the housing program, as well as the stimulation and protection of small rural business, all require a legal infrastructure in the rural area which in many developing countries still remains to be developed. The Basic Needs Model also seems to call for a systematic extension of the judiciary to the village level. A revived rural sector needs a greater conflict resolution capacity. Traditionally, it has been the village headman who, alone or with a few other village officials, adjudicated conflicts and acted more or less as a justice of the peace. In many countries he has now become a major implementer of development programs, and as such has inevitably become a party to many disputes. Such a breakdown of traditional judicial mechanisms has created the need for a place where and a way through which the villager can seek legal redress for real or perceived injustices done to him.

Political Dynamics and Ideological Implications

This enumeration of national policies which constitute the macro-policy framework required for the effective implementation of the Basic Needs Model, although inevitably incomplete, serves to bring out that the Model, in the present state of articulation, cannot yet serve as a development strategy. The Basic Needs Model expresses a particular emphasis and a particular approach to the development process, and presents specific points of intervention. It becomes meaningful only when it is firmly set within a framework of regional and national development policies that are capable of coming to grips with the structural impediments to such changes in emphasis. The

enumeration of these national policies also makes clear the fundamental nature of the changes that these policies call for. Changing the balance between the urban and the rural sectors, between the center and the periphery, reallocation of resources in favor of the countryside which can mean reducing consumption of the elite, opening the door of national socio-economic and therefore political life to the active participation of hitherto disenfranchised groups of the population, the broadening of the political power base that this entails--all these, taken together, amount to a fundamental change in the distribution of economic and political power. Bringing about such changes entails grave political risks to any government seriously committed to implementing the Basic Needs Model. At the same time, the risks involved in not dealing with the problems of employment and equity may, in the long run, be even greater. There is therefore a tradeoff between present and future risks. Be that as it may, it should be realized that despite the often authoritarian character of governments in developing countries, their political systems remain fragile. (Maybe one should put it the other way: they act in authoritarian ways because their power is so fragile.) These political systems have in several important cases proven to be incapable of making the adjustment from growth to equity goals. There are evident limits to the capacity of any political system to make a fundamental adjustment of this kind within a short period.

The experiences of some previously democratic developing countries have shown that, stretched beyond a certain point, political systems can collapse through the breakdown of national consensus and social cohesion, erosion of the center, and polarization, thereby plunging the nation into a tailspin of irrational violence from which it almost seems impossible to recover. Such a collapse can take place not only when the problems of equity as a paramount objective continue to be disregarded, but also when the effort to address the equity problem is in fact made and meets strong resistance. The Basic Needs Model therefore represents not just a shift of emphasis in the development effort, nor is it merely a matter of intellectual perception automatically leading to appropriate behavior, or the simple application of moral principles. Neither can it be implemented through the application of technology, funds, or technocratic methods alone. It is a profoundly political enterprise, affecting vested interests and real as well as perceived threats to those interests, often evoking primordial fears and violent reactions. It means also, possibly for a considerable period, a slower growth rate, slower capital formation, and therefore a slower development of the modern sector (with its own legitimate interests), and the postponement of a nation's capacity to improve its position in the international division of labor.

The international debate about the Basic Needs Model so far has not satisfactorily clarified how it would fit into a socialist system,

or into a society organized on the basis of a classical market economy, or a mixed economy. While the Basic Needs Model is usually taken as an ascent to freedom, its programmatic features lend themselves quite easily to the application of paternalistic and authoritarian methods of implementation. Indeed, the full realization of all the economic, social and political implications of the Basic Needs Model seems to invite, though it does not necessarily require, a degree of state intervention and control which only a totalitarian state would be capable of generating and maintaining. This, however, would undoubtedly destroy the opportunities to develop among the poorest part of the population. It would halt the free development of their organizational, managerial and self-assertive powers through which a greater range of choices will open up to them, and through which greater social effectiveness and the social conditions for human rights and freedom can become possible. These would be crushed under the weight of either a technocratic or revolutionary party bureaucracy, be it from the left or from the right. On the other hand, without such an all-pervasive set of national policies, the Basic Needs Model would soon be reduced to a scheme for the supply of food and basic services, with little change in the condition of powerlessness and dependency of the poorest. Thus, freedom is in itself a "basic need" if the meeting of basic material needs is to lead to emancipation and self-reliance.

We are faced here with a crucial contradiction inherent in the development process. On the one hand there is the need for strong central power and economic rationality from the top, capable of bringing about major structural changes and a rational allocation of limited economic resources. On the other hand, the building of a participatory society requires freedom as an essential condition to develop the capacity of a society to organize itself. Local autonomy, self-reliance and socially effective participation at the village level are inalienable parts of that freedom. No developing country, neither China nor Tanzania, Brazil nor Kenya, seems to have been capable so far of satisfactorily reconciling these conflicting demands. It would therefore seem that the importance of the Basic Needs Model does not lie so much in itself, but in its being a potentially important building block in a democratic theory of development, still to be formulated.

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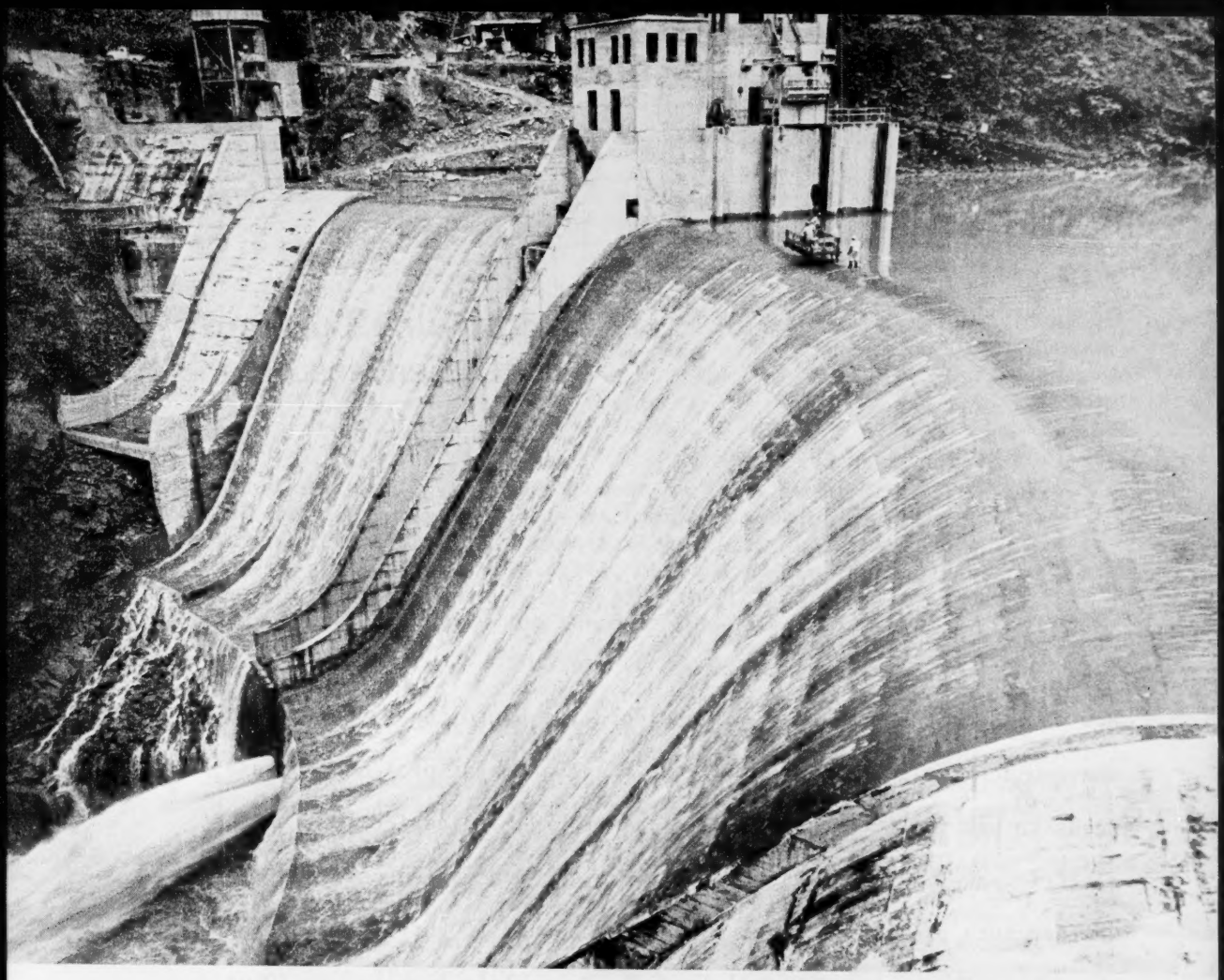
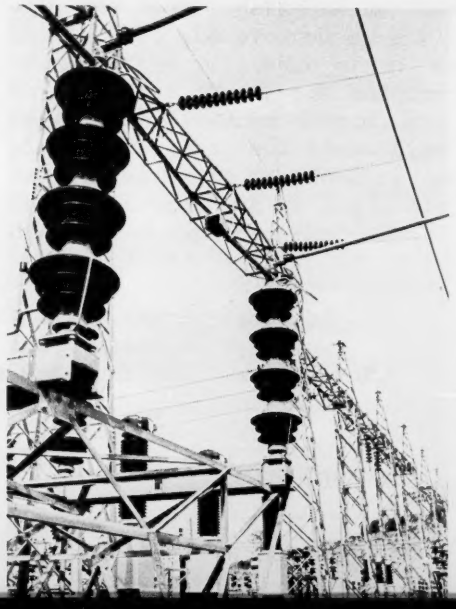
Note: The views expressed here are the author's and do not necessarily reflect those of the Indonesian National Development Planning Agency



PROJECT EVALUATION



How well does the completed dam project live up to the expectations of the project design? Evaluation, the final stage of project analysis, seeks to provide the answer. Dams can provide irrigation for farming, electric power, and drinking water. Project evaluation assesses whether such project services are available and if they are reaching the project's targetted beneficiaries. Colombia's Anchiya dam (Photo: World Bank); Brazilian electricity installation (Photo: The World Bank); Burmese irrigation scene (Photo: United Nations); and Water pump, India (Photo: U.S. AID).

Program Evaluation in AID: Some Lessons Learned

Herbert D. Turner

[Program evaluation as an instrument for management and policy formulation has grown rapidly, in developed and developing country governments and in multilateral organizations. This paper attempts to summarize a few of the principles, methods and operational lessons learned in program evaluation in AID (the U.S. Agency for International Development) during the past few, eventful years.]

In this paper, we define program evaluation as the retrospective analysis of experience to see if we achieved our stated objectives, and to determine how and why it happened. Thus, program evaluation is concerned with results, as distinguished from project or program "appraisal" before an activity has begun. It is useful to differentiate program evaluation from routine implementation monitoring, and at the same time to note their interdependence. Both are concerned with results; but all monitoring is done while a program is ongoing, while evaluation may or may not occur after the external support to an activity has been completed.

Program evaluation is a discontinuous function. The evaluator is disengaged from day to day operations and, one hopes, detached emotionally and intellectually from the program or project. The evaluator examines the relevance of and need for the project; he questions the design and the underlying assumptions; he assesses induced change, and progress toward planned targets; and identifies unplanned change. He then attempts to identify causal factors and assess their effects; and he feeds his findings into redesign and improved execution. Implementation

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monitoring on the other hand, is a continuous function. The monitor is intimately engaged in day to day operations and is usually emotionally and intellectually involved in the program or project. (Sometimes the evaluator and monitor may be the same; this requires a shift in attitude and behavior during the evaluation.) The monitor is concerned with the procurement, delivery and installation of resource inputs; with adherence to implementation plans; and the compliance with required standards and procedures. The two functions are interdependent and necessarily somewhat overlapping. The monitor generates and collects progress data needed by the evaluator; the monitor may call for an evaluation when difficulties arise; the evaluator's findings are translated into replanning actions and implemented by the monitor.

Purposes

The purposes of program evaluation in most development agencies are several:

1. As an integral element in project management, evaluation is concerned with current project performance or effectiveness, and should include regular periodic evaluations of all ongoing projects on a decentralized basis for purposes of redesign and improved execution. This performance evaluation is intended to deal with three considerations: A. Reaffirming the continued relevance of the project in the light of changes over time in host country circumstances. B. Measuring progress toward planned targets, and where progress is discernible during implementation, examining unplanned results at the impact level. C. Determining causality, i.e., what internal elements of project design and/or what external factors affected project performance, and how they operated.

2. As a device for improving resource allocation and management of the projects within a program, evaluation would be concerned with impact or significance. It would consist largely of centrally-managed, highly selective "ex-post" studies in depth of the impact of individual projects and sets of projects on development goals, undertaken after the projects have been completed. These evaluations would complement the interim impact measurements noted above, and would focus on those situations where project impact on sector or program goals was readily apparent only after project termination. The objective is the distillation of operationally useful lessons for application elsewhere. Such evaluations differ from the performance evaluations noted above in that they require a greater investment of skills and other resources, as well as more extensive and intensive data collection and analysis.

3. As a means of policy formulation, evaluation is concerned with the retrospective examination of more general program issues which are neither particular to one program nor country-specific. These could

include such subjects as the role of agricultural credit in rural development, the effects of price policies on agricultural production, or the impact of land reform or land tenancy arrangements on rural development, etc.

Principles

Several operational principles have emerged from recent experience which govern the design and evaluation practices of a development organization.

1. The effectiveness of the evaluation process is very much dependent upon the quality and rigor of program or project design, and the explicitness of its description in the record. The quality of design is often the major limiting constraint in evaluation.

2. Evaluation must encompass a total program or project. It is neither feasible nor productive to limit the evaluation process to the fractional resource input of a single source or donor among several.

3. Evaluation should be decision-driven, that is, it should be undertaken only in response to a need either for a decision on a specific program, or for the formulation of plans, programs or policies based upon the evaluation findings. Consequently, evaluations findings should, so far as possible, be packaged and timed for the needs of the decision makers.

4. The responsibility for evaluation should be placed, functionally and organizationally, as close as possible to the user who will base his decision on the evaluation findings, i.e., the feed-back loop should be as small as possible.

5. The host country ought to take the leading role in evaluating donor-assisted projects, with the donors playing a supportive role. Where the host country wishes to do so but does not have adequate capacity for evaluation, the donors should offer training in evaluation methodology both on a general basis and on a project-specific basis.

6. In designing and implementing evaluation studies, maximum use should be made of host country skills and resources, e.g., local universities, consulting firms, etc.

7. Achieving the maximum transfer and utilization of evaluation findings to similar projects or programs in other countries requires an information system capable of collecting, storing, matching, retrieving, and disseminating such experiental data.

The Preconditions for Evaluation

The key element in both project design and evaluation as practiced in AID is the establishment of a logical framework for the project. AID's logical framework assists the designer to structure project designs in the following ways.

1. A causal hierarchy of project inputs, outputs, purpose, and higher goal in measurable, or at least objectively verifiable terms, is defined as follows:

Project inputs are the human, material and financial resources put into a project.

Project outputs are defined as the specifically intended kind of results (as opposed to their magnitude) that can be expected from good management of the inputs provided. Outputs are also the preconditions necessary to the achievement of project purposes. Example: Manpower, training, machinery and building materials (inputs) can be managed to produce an irrigation network, a trained operational staff, a water utilization schedule and a user rate scale (outputs).

Project purpose is defined as the result which is expected to be achieved, or the problem which is to be solved, if the project is completed successfully and on time. Example: An irrigation network and associated facilities and services (outputs) are intended to produce an increased per-hectare crop yield (project purpose).

Sector or program goal is the next higher objective to which the project is intended to contribute. Example: Increased per hectare yield (project purpose) is intended to result in expanded exports of agricultural crops (sector goal).

2. It is then necessary to hypothesize the causal (means-end) linkages between inputs, outputs, purpose and goal. At each of these levels targets must be met before the next higher target can be achieved. The fulfillment of targets at one of the levels does not, however, guarantee that the next level target will be achieved; factors outside the project design--farmer attitudes, access to credit--may prevent achievement of the next level. Thus the causative relationship between two levels in the hierarchy must be stated as a hypothesis: The external factors must be explicitly identified, and assumptions made about their behavior and probability of occurrence. The evaluator must then verify whether or not the hypothesis was realized.

3. To do this one must articulate the assumptions about external influences and factors which will affect the causal linkages--external situations or conditions which must be assumed to exist or to be

brought about if the project is to succeed, but over which the project management team has little or no control. Example: increased crop yield (project purpose) will contribute to expanded export of agricultural crops (sector goal) but only if price and market conditions are favorable (assumption). The basic premise here is that the achievements and conditions specified for each level in the causal hierarchy ought to be not only necessary but also sufficient to cause the next higher level to be achieved. Each causal linkage must be tested to assure that a given target level (e.g. of outputs), in concert with the assumed conditions at that level, are necessary and sufficient to achieve the next level (purpose). At the purpose-to-goal linkage, it must be recognized, the necessary and sufficient conditions must include not only projects but also a number of nonproject initiatives (e.g., institutional, policy and other reforms) contributing to the pertinent goal.

4. The next step is to establish the progress indicators which will permit subsequent measurement or verification of achievement of the defined outputs, purpose, and goal. Progress indicators are preestablished criteria or specific measures designed to provide objective assessment of project progress. Progress indicators should be so objectively stated that both a proponent of a project and an informed skeptic can agree that progress has or has not been as planned. Pre-establishing objectively verifiable progress indicators and targets helps focus the subsequent discussions on the evidence rather than on diverse opinions.

This logical framework is primarily a project planning device. It also is used for reexamination of the original design of ongoing projects as a necessary prelude to evaluation. It sets the stage for determining, and then validating, whether or not the project outputs are being produced; whether these outputs in fact are serving to achieve the project purpose; and finally, whether this achievement is making a significant contribution as planned to the higher order goal. The logical framework also is used to set the practical limits for responsibility of project management. Articulating the project planning assumptions in explicit and operational terms permits a clearer separation between manageable interests and those factors which appear to be beyond the control of the project management team. The input-to-output level is largely susceptible to managerial control with relatively few uncontrollable external factors. At the output-to-purpose level, the possibility of managerial control decreases while external factors become more important. At the purpose-to-goal level, the ability of project management to predict and control events usually is further diminished.

In addition to the logical framework elements noted above, the project design process should also contain such evaluation information and actions as:

...Collection of "baseline data" on conditions before a project has been started.

...Review of prior experience with similar projects elsewhere, to the extent possible.

...Provision for experimental, quasi-experimental or other evaluation approaches intended to bring out more materials for judgment than those elicited by routine reporting methods.

...Establishment of schedules for recurring evaluations, with timing keyed to decision making. For ongoing projects, if these evaluation elements and actions were not built into the design, evaluation will be difficult.

Experience in evaluating ongoing development programs or projects has shown: 1.) For most projects it is not possible to evaluate progress toward established targets in a meaningful way until the evaluator has considered any changes in the host country socioeconomic setting which may have significantly affected the project, and the existing project design has been reexamined and clarified. 2.) The first of these considerations, the assessment of changes in the host country socioeconomic setting, may well be demanding and difficult, requiring data collection and analysis as well as extensive discussion with all collaborating agencies. It includes such questions as: a. Changes in the nature and magnitude of the problem to which the project is addressed. b. The continuing validity of original feasibility data and estimates. c. Changes in physical and environmental conditions. d. Changes in demand and other economic variables. e. Changes in attitudes and other social variables. f. Changes in host country development policies and priorities. 3.) When this assessment of changes in the project setting results in substantial redesign, it may not be possible to evaluate progress toward the new targets immediately. Depending upon the extent of the redesign and the revised implementation plan, it may be appropriate to postpone the evaluation for a year or more.

Kinds of Evaluation

There are several forms and types of evaluations used in development organizations.

Formative evaluation is used when the project purpose is not readily definable in precise and explicit terms, and when the strategy for achieving that objective is even less clearly understood. In such circumstances formative evaluation is used periodically to explore experience to date in order to permit managers progressively to sharpen the definition of the purpose and to formulate a viable strategy for achieving it.

Summative evaluation is used when the objective is clearly defined and there exists a high level of confidence in the strategy for achieving that objective. In this instance summative evaluation merely attempts to measure progress towards the objective.

The goal attainment evaluation model is used when the project or program has a single predominant objective. This model is widely known and used; it is relatively low-cost and imposes modest skill requirements.

The systems evaluation model is utilized for institution building and for complex projects or programs with multiple (and possibly competing or conflicting) objectives. It is not yet widely used because it is not well understood and its cost is high in terms of the skills required.

Many institutions engage in an either/or debate about the comparative advantages of ongoing evaluation versus ex-post evaluation of completed programs or projects. Both are needed. Evaluation of ongoing projects is a program management function intended to: 1. assure the efficient use of scarce resources; 2. measure effectiveness in achieving planned project objectives; and 3. confirm the continuing relevance of the project in the light of changing circumstances. Ex-post evaluation of completed projects is a program policy and management function and is intended to: 1. give a final accounting to the sponsors and supporters of the project; 2. identify possible follow-on opportunities for the host country; and 3. derive lessons from past experience which can be applied to the design of similar projects and to the formation of program criteria and policy.

Measurement and Verification

The design of the program or project rests on a structured hierarchy of objectives (inputs-outputs-purpose-sector or program goal) connected by hypothesized causal linkages (e.g., if outputs, then purpose). The task of the evaluator is to verify these hypotheses. If the project design provides for the evaluative preconditions described above, then measurement and verification can be relatively simple and routine--i.e., measuring change using the previously formulated progress indicators, and drawing on the progress data collected during implementation. Program and policy evaluation, involving aggregations and inter-country comparisons of projects and programs, generally follows the same basic evaluative process as is followed in project evaluation.

If the desired changes did not occur, or if they occurred but some explanation is needed of how and why they occurred, then the evaluator must delve deeper. A lack of resources and the operational

conditions in the less developed countries have usually inhibited any extensive use of experimental or quasi-experimental project designs, except in special cases. But this does not reduce the need for analytical rigor in design and evaluation: it is possible for the evaluator to simulate the rigor of a controlled experiment by the proper use of baseline data, by explicit definition of targets, and by the retrospective verification of project hypotheses.

Such retrospective verification includes careful examination of the nature of the processes through which the hypothesized causal linkages occurred or failed to occur. Verification or validation of hypotheses might be approached through direct observation; by the use of proxy or surrogate measures; by examination of differences in results or impact among target subgroups within the treated areas, and of the independent variables associated with those differences; or by statistical techniques such as multivariate analysis, etc. Verification could also be approached by formulating alternative hypotheses to explain changes. But if none can be developed, or if plausible explanations can be disproven, this suggests at least partial validation for the original hypotheses. Conversely, if alternative hypotheses can be supported to the point that they become persuasive, then the original hypotheses lose credibility. While such retrospective methods would appear less satisfactory than the classical experimental design, the operational realities of a development assistance program usually favor the indirect method.

Evaluation findings should be reviewed to establish implications and conclusions for further action. The review should include all interested parties: the host country, the implementing agents, all donors. The climate should be collaborative and constructive, not threatening; improved planning, not recrimination, is the intent.

Roles and Relationships

Two closely related pairs of issues require thoughtful consideration. 1.) Should the evaluation responsibility be centralized (with evaluations performed by a central evaluation unit), or decentralized? The critical criterion is that responsibility for conducting evaluations should be located functionally and organizationally as close to the decision-making point as possible, so that the feedback of findings into decision-making should be as direct and immediate as is practical. Application of this criterion suggests that: A. Evaluation of progress during a program, and of the continuing relevance of individual projects, be decentralized to the project management team. B. Evaluation of experience, usually after project termination, to formulate policy and program criteria be done by a centralized unit concerned with policy and program coordination. C. Evaluation of programs and groups of projects for routine program management purposes be done at an intermediate level, e.g., regional or technical offices.

2.) Should evaluations be conducted by in-house staff (e.g., those with program or project implementation responsibilities) or by outside experts? Operational experience shows that project managers can evaluate progress and the continuing relevancy of their own projects candidly and objectively if there is a climate of constructive inquiry rather than a climate of recrimination. There are simple criteria to guide the choice.

IN-HOUSE	OUTSIDE EXPERTS
-- Greater knowledge of the environment and of specific operations is required.	-- Disinterested objectivity is paramount and must be demonstrated.
-- Direct and immediate feedback of findings into replanning.	-- Greater and more recent technical knowledge is required.
-- Lower unit cost - broader evaluation coverage.	-- Evaluator must be free from operational workload for extended period.

It is a matter of emphasis rather than an either/or choice. Both kinds of evaluation are needed, and a combination of in-house and outside experts often provides the best arrangement.

Irrespective of how many program evaluation activities are decentralized, there is always a need for a central program evaluation unit to assure that evaluation is occurring and that it is professional and rigorous, and addresses operational concerns; that evaluation components are built into programs and projects; that effective methods or techniques are available, understood, and used skillfully; and that findings are channeled into replanning and decision-making.

[Extracted from an internal document of the U.S. Agency for International Development, July 30, 1976. Published in Focus, No. 3, 1976, pp. 26-30. (Focus is a supplement to the International Development Review, published by the Society for International Development.)]

The Heptar Fertilizer Project: An Example Illustrating AID's Evaluation Method

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[The following example illustrates how the evaluation method employing AID's logical framework, described in the preceding article, can be applied to a particular project. The illustration is taken from AID's training course in the evaluation method, and concerns an imaginary country called Heptar.]

Background Data: Heptar Fertilizer Project

Heptar is one of the least developed countries in the world. A landlocked nation, it encompasses roughly 250,000 square miles of substantially mountainous or arid wasteland. The soils are characteristically sterile as they are high in alkaline and calcium and low in organic matter. Consequently they are unfavorably suited for high crop production, a problem further magnified by low or intermittent rainfall, occurring primarily in the period from November to May and averaging 10 to 20 in. per year. The most important sector is agriculture. The most important crop and diet staple is wheat. Primary exports are livestock, cotton, and sugar. Other important crops include corn, rice, fruits, nuts and barley. More than 80 percent of the population is directly dependent on agriculture. Even though Heptar is not a heavily populated country in terms of total land area--population estimates are 16 million with a two percent annual increase--the pressure on the arable and irrigated land is heavy. Per capita income is less than $100 per year, and perhaps only $35 for the rural majority.

The Government of Heptar (GOH) has placed strong emphasis on becoming self-sufficient in agricultural

production, especially in wheat, as the key to economic improvement. The strategy has focused on encouraging the use of, and making available, chemical fertilizer--di-ammonium phosphate (DAP), and urea. In 1972, after consultation and advice from international donor agencies, the Heptar Fertilizer Company (HFC) was established as the government enterprise responsible for producing and distributing fertilizer to all parts of the country. HFC also plans to include such agricultural products as pesticides, veterinary pharmaceuticals, and sprayers in a distribution system located in every significant farming/market area in Heptar. Moreover, the GOH is subsidizing the price of imported fertilizer to maintain a low farm price on the chemical fertilizer and thus encourage small farmer use. Currently 85 percent of fertilizer sales to small farmers are financed through the Agricultural Development Bank. As a result, fertilizer use has increased, although it is still quite low in the case of subsistence farmers, defined as farmers who plant less than 10 kyahs (4.8 acres) with wheat.

Fertilizer is, however, in such short supply that no more than five to eight percent of Heptar's irrigated land can be fertilized each year. Presently, 75 percent of the fertilizer is applied to wheat, with most of the balance applied to sugar and cotton. The alternative to not using increasing amounts of commercial fertilizer is the importation of wheat. However, the economics are clearly in favor of increased fertilizer use over wheat imports, as the cost/benefit ratio is around 3:1 in favor of increased fertilizer use.

AID assistance. AID's involvement in the HFC project, to begin June 1976 and end December 1978, is to assist the GOH to achieve its goal of increasing the income of small subsistence farmer families who account for 70 percent of the population. It is anticipated that increased small farmer income will be achieved through increased agricultural production, which will--it is hoped--be a direct result of the AID project purpose--to increase small farmer use of fertilizer. The main thrust of the project will be to build a viable, self-sustaining management system within HFC. Improved management capabilities will increase HFC's capacity to procure and distribute both domestically produced and imported fertilizer to farmers. This, in turn, should lead to increased use of fertilizer by small farmers in particular. Concurrently, this will result in higher agricultural yields as additional amounts of fertilizer are applied to the principal crops--wheat, cotton, and sugar beets.

AID will provide the services of: three advisers for 30 months each, a number of short-term specialists, and contractor home office support as well as participant training. The three advisers and short-term specialists will work with the HFC Executive Committee and will assist in furthering the development of the business capability and efficiency of the company. In addition, AID has provided

provided development loans totalling $27 million for the importation of fertilizer. In the past, other donor agencies have assisted in establishing the management structure at HFC through loans for financing management services (from 1973 to 1975), and through advisory service grants (from 1975 to 1976). A quick evaluation of HFC operations and performance was carried out by one of the donors in November 1974. The major findings of this evaluation led to a recommendation of additional technical assistance and management training at HFC.

The Government of Heptar and HFC contributions. The GOH has taken several steps to increase the availability and consumption of fertilizer. There have been sporadic campaigns as well as long-term programs conducted by the Ministry of Agriculture's Extension Service: fertilizer trials have been conducted, fertilizer production has been subsidized, one urea plant has been constructed, and a fertilizer credit program has been developed with emphasis on ways to finance small purchases. Additional GOH contributions to this project consist of: 1. Subsidies to HFC operating budget; 2. Housing for US AID advisors; 3. The services of one full-time bilingual secretary to the advisory team, to type 40 wpm or better; 4. Administrative support for the foreign advisors and their project activities including, but not limited to, office space and equipment, official transportation, office supplies, road passes, permits, visas, customs clearances for commodities, and translation services; 5. Trust funds administered by U.S. AID/GOH to cover participant travel costs on government airlines and, as available, funds to pay for U.S. contractor support.

Other external support. In the past 20 years there has been considerable foreign assistance in Heptar. As far as fertilizer is concerned, the U. N. Development Program, the Germans, the Japenese, Russians, Saudi Arabians, Iraqis and Kuwaitis have all made varying amounts of fertilizer available under a wide variety of concessionary terms, including grants. Such assistance is likely to continue, but gradually diminish. The World Food Program, IBRD, Agricultural Development Bank, and the UNDP have projects underway promoting agricultural credit, cooperative development, irrigation, and rural roads--projects essential to the success of the fertilizer project. However, no donor apart from the U.S. has shown any interest in fertilizer distribution as such, and is not likely to do so in the forseeable future. Hence, the AID involvement.

Project Design

Trainees are asked to draft a project design in accordance with AID's logical framework (described in the preceding article). The next page shows how this is done; the draft design is followed by a check list of aspects to consider when the design is finished but might need revision.

PROJECT DESIGN SUMMARY
LOGICAL FRAMEWORK

G.P.O.1.	OBJECTIVELY VERIFIABLE INDICATORS	MEANS OF VERIFICATION	IMPORTANT ASSUMPTIONS
Program or Sector Goal:	Measures of Goal Achievement:		Assumptions for Achieving goal targets:
To increase small farmer income.	Beginning in 1978: Annual increases in small farmer purchase of: Bicycles - 5% Oxen - 3% Cloth - 10% Transist. Radios - 10%	US AID/GOH survey of small farmers' purchases: 1976, 1977 and 1978. Visual observations.	GOH price support program (in wheat, cotton, and sugar) for small farmers being carried out.
Subgoal:			
To increase agricultural production of small farmers.	Annual increases in small farmer agricultural production by 1977: Wheat - at least 3% Cotton - at least 10% Other - at least 5%	Ministry of Agriculture Reports.	Agricultural Development Bank (ADB) will continue to improve its credit program, including credit to small farmers.
Project Purpose:	Conditions that will indicate purpose has been achieved:		Assumptions for achieving purpose:
To increase small farmer's annual usage of fertilizer.	1.a. Number of small farmers using fertilizer increased from 33,685 in 1974 to 65,000 in 1978.	HFC Records and Reports US AID monitoring of HFC operations.	No natural disasters or insect infestations.
	1.b. Amount of fertilizer sales to small farmers increased from 13,424 MT in 1974 to 24,543 MT in 1978	ADB Reports Survey of retailers	Other donor and GOH agricultural sector activities which impinge upon the project purpose are maintained at current levels of effort and efficiency.
Project Outputs:	Magnitude of Outputs		Assumptions for achieving outputs:
1. HFC is independently producing timely, comprehensive, and realistic plans	1.a. Plans for 1977 and 1978 prepared and approved before beginning of respective years.	HFC records and reports. US AID monitoring of HFC operations, US AID evaluation.	HFC remains an independent business entity in accordance with the terms of the charter.
	1.b. HFC management prepares quarterly progress targets starting June 1977.		Small farmer participation in HFC fertilizer distribution program.
2. HFC operates without advisory assistance at national and international levels.	2.a. Top management is conducting international business transactions including international fertilizer procurement by Sep September 1978.	GOH reports. HFC records and reports	US AID advisors terminate assistance to HFC by 1978.
	2.b. HFC conducting national business transactions including fertilizer distribution independent of foreign advisors by September 1978.	Site visits by US AID to HFC checking on fertilizer procurement and distribution.	
3. HFC has developed a distribution network with adequate supply and marketing capability.	3.a. Delegations of authority from HFC HQ to district branches operating effectively by June 78.	HFC monthly survey of distrition.	
	3.b. One or more retailers operating in each agricultural district by Sept. 77.	GOH agricultural extension service records. US AID monitoring of HFC.	
	3.c. Warehouses using orderly operational procedures including inventory systems by early 1977.	HFC reports.	
	3.d. Inventory losses 0.5% of sales by end of 1977.	HFC records and reports.	
	3.e. Procurement at least 6 months ahead of demand by 1977.	HFC records and reports.	
4. HFC markets other agricultural inputs.	4.a. Sales of other agricultural inputs are $2 M by 1977 and $2.5 M by 1978.	HFC records and reports.	

EVALUATION FACTORS TO BE CONSIDERED IN THE LOG FRAME AT PROJECT DESIGN STAGE

Consideration	Definition	Level	Response	
			Yes	No
Plausibility	Are the indicators appropriate measures of the respective objectives the project is trying to produce?	Goal		
		Subgoal		
		Purpose		
		Output		
Independence	Are indicators at the goal, subgoal, purpose, and output levels distinct from each other?	Goal		
		Subgoal		
		Purpose		
		Output		
Objectivity	Could both a skeptic and an advocate of the project be expected to agree on the facts shown by the indicators?	Goal		
		Subgoal		
		Purpose		
		Output		
Targetting	Are indicators explicit in amount, time, and (if appropriate) place and/or group at which the project is aimed?	Goal		
		Subgoal		
		Purpose		
		Output		
Comprehensiveness	Do the indicators tap all major aspects of the objectives to be achieved so that no additional indicators are needed?	Goal		
		Subgoal		
		Purpose		
		Output		
Verifiability	Are the information sources listed in Column 3 of the Logical Framework reasonably available or accessible?	Goal		
		Subgoal		
		Purpose		
		Output		

Evaluation of Heptar Fertilizer Project as of September 1978

Trainees are to make up an evaluation of this project, using AID's logical framework. This evaluation must deal with the following questions in order to determine the extent of the project's effectiveness:

At the output level -

1.) Is HFC now operating without advisory assistance?

a.) Data Source: Records, including correspondence and documents.
b.) Location: HFC and/or U.S. AID Mission.
c.) Collection Method: search files, get copy or make notes.
d.) Degree of precision needed: normal.
e.) Hypothesis: HFC top management is now conducting international business transactions, including fertilizer procurement.
f.) Analysis: Find evidential records to support or refute the hypothesis.

2.) Has HFC developed an adequate distribution network? Hypothesis: At least one retailer is operating in each agricultural district as of Sept. 1977. [Other items a.) to f.) are similar to those in question no. 1.]

3.) Is HFC now marketing agricultural products other than fertilizer? Hypothesis: Sales of other agricultural inputs were $2M by 1977 and are $2.5 M in 1978. [Other items similar.]

At the Purpose Level

4.) Has small farmers' usage of fertilizer increased? Hypotheses: Either 1a.) Number of small farmers using fertilizer has increased to 65,000 by late 1978; or 1b.) Total amount of small farmer fertilizer sales has increased to 24,543 MT by late 1978. [Other items similar, but more precision in data is needed; late 1978 consumption rate must be compared with "baseline" figure before project was begun.]

At the Sub-goal Level

5.) Has agricultural production of small farmers increased? Hypothesis: 1977 wheat production has increased at least 3% over 1976; 1977 cotton production has increased at least 10% over 1976; 1977 production of other crops has increased at least 5% over 1976. [Again more precision in data is required to compare pre-project production levels.]

Factors Outside Log Frame

If the suspected discrepancy between fertilizer utilization (purpose level) and agricultural production (sub-goal level) is actually found to exist, the evaluation must look into the following:

1.) Is rain a plausible reason?
   a.) Data Source: Precipitation tables.
   b.) Location: Heptar Meteorological Inst.
   c.) Collection Method: Get precipitation records for 1977.
   d.) Degree of Precision needed: Exacting.
   e.) Hypothesis:
      1) Rainfall for 1977 was significantly greater than average.
      2) Rainfall for April 1977 was abnormally high.
   f.) Analysis: Compare 1977 mean rainfall with previous years' data.

   Compare April 1977 data to determine its deviation (t-test, chi-square, or other).

2.) Are the retailers actually giving the farmer/customers the needed instruction and demonstration on proper application of fertilizer?
   a.) Data Source: Records
   b.) Location: HFC
   c.) Collection Method: Search files, make notes
   d.) Degree of Precision needed: Normal
   e.) Hypothesis:
      Retailers are providing proper instruction and demonstration to the farmers.
   f. Analysis: Find evidential data to support or refute the hypothesis.

Summary of Evaluation Results

An evaluation of the Heptar Fertilizer Corporation operations had been held in November 1974. The HFC, it was found, had succeeded in establishing its identity and integrity as a government corporation; it was managing its own activities with the help of technical advisors. Additional management advisory services appeared to be required, however. This study was done by the UNDP.

In 1975 the U.S. AID Mission in Heptar took an interest, and developed a project proposal which was then approved to start in June 1976. An evaluation was conducted after one year (August 1977) to determine the alignment of the project design with the realities of the situation in Heptar at that time; the tenability of the assumptions; the quality of the input process; the progress toward output

targets. The evaluation was to have been carried out by a joint U.S. AID/HFC team, but shortly after it began the AID officer concerned was evacuated from Heptar for medical reasons. The evaluation was completed solely by HFC staff, and is believed to be unreliable since they were evaluating themselves. This evaluation turned up evidence to show that the original design of the GPOI (Goal, Purpose, Output, Input) was faulty. Linkages between output and purpose and sub-goal did not follow through. Not all outputs were obtained, but the purpose was achieved. The purpose was achieved, but the sub-goal was not reached. Several hypotheses were tested to explain the findings. It is now believed that the small farmers were not trained properly in the use of fertilizer, and that many of them reduced their yield by overfertilizing; but the evidence for this is not firm. The project is still of interest to AID in its agricultural sector program. It is considered that additional money to support better training of the small farmers for an additional two years will be a sound investment.

Purpose: The project purpose, "to increase the small farmer's annual usage of fertilizer," was achieved, but under peculiar circumstances. Several of the outputs were not attained. The achievement of the project purpose was probably attributable (we are not sure) to an overzealous sales staff, rather than to the attainment of the outputs.

Sub-Goal: The sub-goal "to increase the agricultural production of small farmers," was not reached--even though the purpose was achieved; thus the purpose-to-subgoal linkage was apparently weak. Wheat production was -1.8% rather than +3.0% as expected. Cotton production was up only 5.6% rather than the 10% expected each year. Other crops (vegetables, fruits, sugar beets) all increased less than 1% rather than the 5% expected annually. The reason for this failure is uncertain, but might be attributable to over-fertilization of the crops due to inadequate training of the small farmers in how to use the fertilizer they bought from HFC. The other possible explanation, excessive rainfall, was tested against the weather records and found not to be the case.

Goal: No data are available yet concerning any changes in the small farmers' income which might be attributable to some contribution from this project.

Beneficiaries: Small farmers and their families are expected to benefit in terms of greater agricultural productivity, the promotion of greater equality in income, and increased opportunities for social mobility. No evidence of any of these is available at this time, however.

Unplanned Effects: A flood in the province of Janpoi washed out a warehouse where HFC had stored large quantities of DAP and urea. There is no retail outlet in that province and no outlet for distribution, so that the amount of fertilizer washed out was an accumulation of almost two years. The flood waters carried the fertilizer for miles around the surrounding countryside, and when they receded they had in effect fertilized the small farmers' crops without any expenditures or efforts by the farmers themselves. As a result, many yields were two or three times their usual level.

Lessons Learned: The weak point in the GPOI design for this project was not readily discernible during the first year of the implementation. An assumption had been made that the small farmers would participate in the HFC fertilizer distribution program; but the further implicit assumption--that they would know what to do with the fertilizer--had not been made explicit, and turned out to be wrong.

[Extracted from training materials used by the U.S. Agency for International Development in its training course in evaluation methods, Washington, D.C., 1979.]

Summary of World Bank Annual Project Evaluations

World Bank Staff

[The World Bank inaugurated in 1971 a process for evaluating the results of its operations in member countries, in an attempt to draw from its experience lessons that might make it a more efficient and responsive development assistance agency. This document is the latest annual report to the Executive Directors summarizing the results of the findings on a group of 70 projects, representing Bank loans and IDA credits totaling approximately $1.3 billion.]

Project evaluation begins after the project has been completed, usually five to seven years after it has been started. For each completed investment, a separate report is prepared comparing original objectives with final accomplishments. It is these individual Project Performance Audit Reports that this review draws upon. They are the products of careful study by Bank operational and independent evaluation staff, and candid and frank discussion--often of a confidential nature--with concerned governments. Because that confidentiality cannot be compromised without compromising the integrity of the reviews, specific project names, as well as names of countries, have been deleted from this published summary. This Annual Review not only summarizes the findings of the individual Project Performance Audit Reports, but highlights overall patterns and draws attention to particular issues that recur with sufficient frequency to warrant deeper scrutiny.

The projects reviewed in this report cover a broad range of Bank activity. The initial loan agreements for most of them were signed during 1969-72, and most were completed in the years 1973-75. The group of 70 is more heavily weighted with utilities and transport than is the current Bank lending pattern, and lighter in DFCs (Development Finance Companies) and education. None of the newest

types of project--tourism, population, urban or nutrition--are represented at all, nor are the newer kinds of integrated rural development projects.

PROJECTS BY SECTOR
(Values in millions of U.S. dollars)

Sector	Number of Projects	Amount of Lending	Actual Project Costs*
Public Utilities			
Electric Power	14	435.1	1,179.9
Telecommunications	2	16.8	35.0
Water Supply	3	11.6	17.4
Transportation			
Highways	12	244.5	591.4
Others	6	138.2	213.6
Agriculture	21	254.7	518.4
Education	3	18.9	31.7
DFCs (Development Finance Companies)	3	28.0	108.0
Industry	5	127.0	581.2
Program Loans	1	30.0	30.0
Total	70	1,304.8	3,306.6

*Total cost of project or program to which loan or credit contributed; some figures are quite approximate.

About half the projects reviewed are in the fields of public utilities and transport--the fields of basic infrastructure in which the Bank's experience is longest. The proportion of agricultural projects in this group, 30%, far exceeds the proportion in earlier Bank lending, and this reflects the growing role of agricultural lending which developed in the late 1960s and early 1970s. DFCs are not as strongly represented in this group as they will be in future reviews; education projects are also fewer than they will be, reflecting the evolving changes in the thrust of Bank lending.

Summary of Overall Results

Project design and scope. It is a fairly common experience for projects to be changed in the course of implementation, so that projects as completed are different from the same projects as initially appraised. Of the 40 projects with specific physical content, 11

were expanded in scope, three of them greatly, and 7 were reduced, one of them substantially. In some cases the original design proved to be technically faulty, or the preparation studies insufficiently detailed to foresee the difficulties subsequently encountered, which led to changes in the original plans. In other cases the scope of the project has been expanded to meet a revised estimate of demand, or new objectives. In some cases projects have been curtailed because costs have exceeded estimates, resources have been limited, and the project content was judged to be divisible. There are also a few cases where some of the original project elements proved to be impractical and had to be dropped.

Increases in scope are frequently accompanied by increases in cost and in execution time. However, even when the project costs more and takes longer to implement, there may be offsetting gains; it may still retain, and in most cases in this review has retained, the prospect for achieving a satisfactory economic return. There are also some cases where one can see in retrospect that more changes in the project might have reduced unproductive expenditures and increased the economic effectiveness of the investment. Considering the process of project formulation and execution and the field context in which projects are carried out, it is almost inevitable that operating effectiveness will be related in some way to flexibility in adjusting to circumstances and problems encountered during the process of execution. The need for such flexibility is particularly important in the newer types of projects where the accumulation of experience is less.

Cost experience. The expenditures on over half of the 57 projects for which cost estimates have been made (this excludes credit projects, cancelled projects and programs loans) were either less than appraisal estimates, or did not exceed them by more than 10%. About one third showed cost overruns of 25% or more; and 15% exceeded estimated costs by 50% or more.

In a number of cases the actual costs of infrastructure projects were less than expected because bids were lower than anticipated; a more common reason was a reduction in the original scope of the project. Reduction in scope was also an important reason for keeping down cost increases in a number of other cases. On the other hand, an increase in project scope, or required changes in project design as a result of unanticipated conditions were major reasons for cost increases. In a number of cases these increases were accompanied by substantial delays in project execution. The largest increases in costs and execution time were associated with the oldest projects included in this Review which had loan agreements dating from the early and mid-1960s. The effect of the 1973-75 inflation on the investment costs of this set of projects is not pronounced: most of the contracts for their construction and equipment were made prior

to this period. However, the credit projects, which are generally of more recent origin and which have generally been kept within original estimates, have financed less investment than originally expected as a result of inflation.

Time to complete projects. The longest time overruns occurred in the fields of public utilities, transport and education, where the completion of civil works and/or the procurement and installation of specific items of equipment were involved. About half of the 62 projects for which physical completion is readily measurable required about 25% more time than estimated; more than one-fourth of the 62 required over 50% additional time to complete. The additional time required for 17 of the 62 projects was over two years. Four transport projects were delayed more than three years.

Some of these delays reflected unrealistic targets, or resulted from actions taken to preserve or enhance project benefits. Many delays represented a real cost to the borrower in benefits foregone. We observe in this review that 30% of projects were delayed roughly one year, 20% two years and 15% three years. Assuming a 10% opportunity cost of capital, the cost of delay could approach 10% of the value of loan commitments for this group of projects. An important factor contributing to the longer delays experience appears to be the quality of project preparation. In several cases the loans were signed before the projects were clearly defined--e.g., one highway loan made before detailed engineering was done, a practice since discontinued except in the case of feeder road projects. In other cases the quality of preparation turned out to be inadequate under the test of execution, and additional expenditures and time were required to complete a satisfactory project. Other reasons for delays were problems with procurement and contractors, unforeseeable problems with weather or geological conditions, and problems of administration and management.

Economic returns. When a project has been completed in the sense that construction is finished, equipment is in place, and the loan or credit has been disbursed, a new estimate of the costs and benefits and the prospective economic return on the project's investment is made in all cases where an estimate had been made at the time of appraisal. [For an explanation of the internal rate of return in project appraisal, see the last Development Digest (April 1979) pp. 87-91.] This revised estimate takes into account the actual investment cost incurred, the actual time required to complete the project, and any revisions of the estimated flow of operating costs and benefits that seem necessary to reflect experience during the execution stage or revised views of future developments. The new estimate is a measure of changed expectations for the project returns as a result of the implementation experience and other changes and thus indicates

whether, in retrospect, the justification of the project at appraisal remains valid. In comparing initial and subsequent estimates of returns it must be remembered that both the original estimates and those recalculated at the time of audit are of varying quality and comparability, and some were very rough approximations.

The transport projects in this group include some with the largest increases in costs and the longest delays in implementation, yet only two of the seventeen transport projects completed show estimated returns at audit of less than 10%. The return on highway investments is measured in terms of savings in vehicle operating costs; in a large number of cases, traffic has clearly exceeded estimates. In addition, the world-wide increase in oil prices has increased vehicle operating costs and hence the level of savings to be realized from improved roads. Even when traffic projections have been overoptimistic, project returns have remained satisfactory. Two gas pipeline projects directly profited from the increased value of gas. However, a shipping project was adversely affected by the decline in ship charter rates, a consequence of the rapid changes in the world's oil markets.

The increase in world oil prices has clearly benefited projects with large fixed costs, low operating costs, and benefits which increase with the cost of fuel. In addition to road projects, hydroelectric plants have also improved their economic prospects, while the selection of thermal alternatives has not worked out as advantageously as planned. In the case of power utilities, the effects of rising labor as well as fuel costs have not been fully reflected in many controlled electric power prices; financial returns thus declined in these cases, even when the economics of the projects have improved. Four of the 19 public utility projects included in this review show incremental financial returns of less than 10%; ten have returns exceeding 10%; and in five cases the return is considered satisfactory although no calculation was made either at the time of appraisal or audit. The particular cases with low financial return are not necessarily examples of an incorrect choice of investment; one of these cases resulted from underestimated costs because of unanticipated geological problems, but most of these low returns reflect a low level of controlled utility prices.

Agricultural projects are distinguished by the fact that the returns are directly related to increases in production by a group of individual producing units, which in some cases is very large and consists of very small units. Furthermore, unlike many infrastructure projects, the increase in production often involves a change in (farm) practices, which cannot be expected to automatically accompany the provision of new public investments and new sources of credit. Some of the attempts to introduce new practices have been

fairly elaborate; not all have been successful. Most of the projects with revised estimates showing low returns are found in this sector. In general, agricultural projects have not benefited as strongly from the movements in world prices as have the transport projects. Some commodity prices have increased during this period to the benefit of some projects; some have fallen. Current costs are relatively large in relation to investment and include an important product, fertilizer, that was directly affected by the increasing cost of petroleum.

For twelve projects, returns were not estimated at the time of appraisal and only qualitative estimates of returns were made at audit. These include the education projects, the DFC projects, the program loan and some industrial projects. In none of these cases was the later qualitative estimate of performance considered unsatisfactory.

Financial returns. For revenue earning enterprises, namely those involved in power, water supply, telecommunications, ports and pipelines, the target rates for financial returns are frequently specified in loan covenants or supplementary letters. The financial returns on power enterprises show a weaker performance than in previous reviews: for seven of fourteen cases, the returns during the early period of operations were lower than specified in loan covenants or estimated at appraisal. To a large extent, this reflects the general inflationary conditions of recent years as noted above. Fuel prices have increased rapidly and labor costs have also risen sharply in many utility enterprises. At the same time, for political and other reasons, electricity rates have not been raised in line with costs. In some cases, governments have elected to provide funds for the enterprises through grants or purchases of equity rather than through consumer payments. Additional factors that have contributed to this result include lower demand than anticipated in three cases. The water supply and telecommunications projects in this review had shown generally satisfactory financial performance at the time of audit.

Institution building. Many of the loans reviewed included provisions to support the establishment of a new borrower institution, or to strengthen the capacity of an existing institution to operate effectively. The emphasis in the latter case was usually on financial management and, in some cases, on general organization and management and training. Specific actions concerning organization, staffing and financial objectives were often the subject of loan covenants or supplementary letters, and provisions to finance consultant services were frequently included in the loan.

In the past, achievement of the institutional aspect of project objectives has generally been less successful than the physical implementation. Whereas the physical objectives have generally been

achieved and this can be clearly determined, the institutional objectives are both less frequently attained and their attainment less easily measured. In this area of operations, differences between Bank and borrower views are most frequent. The Bank does seek to support high standards of performance by borrowing entities; but these standards are often exceptional in the borrowing country, and the management methods supported frequently represent a substantial change from existing practices. So the process of change which the Bank supports, even when it is carried out successfully, frequently takes longer than was anticipated in the project appraisal.

The projects included in this Review illustrate a variety of institutional efforts:

(a) Establishment of a new institution to perform a new function much broader than that directly supported by the Bank loan. Examples are a Development Finance Company (DFC) in Africa, and Agricultural Development Banks in the Middle East and Latin America.

(b) Establishment of a new organization with the immediate purpose of carrying out the proposed project, which may or may not be expected to assume a broader role in the future. The approach was adopted in the case of livestock and cooperative farm projects in Africa, where the Bank played an important role in setting up autonomous project units.

(c) Support for improving the performance of an existing enterprise. This is best illustrated in the public utility projects: in several cases, the Bank supported the installation of modern management practices with particular focus on financial management, using firms of management consultants to design the changes and assist in their implementation. In several cases reorganization of the enterprise along more commercial lines, as planned with the Bank, preceded the loan.

(d) Support for improved organization, planning and operating practices in a government department. Some highway loans provide examples. Finance for consultants to recommend changes in organization and practice was provided in the loans.

The Bank's efforts to help strengthen the borrowers' administrative and technical capacity appear to have been substantial in a considerable number (27) of the projects reviewed. The results of these efforts have been mixed. Where the proposed action was not strongly supported by the borrower, the efforts of consultants and the Bank and the assistance of covenants have had limited effect. It was noted that support by the borrower has been weak where he does not perceive some particular problem to be of highest importance,

i.e. where expected benefits from the efforts required may not be seen as clearly worthwhile. Sometimes the actual design of the proposed change may contribute to this perception, or the case made for the proposal may not be thoroughly convincing. On the other hand, if the attempt to strengthen an institution is poorly designed it may fall on its own, even when accepted by the borrower's management.

Sector Review and Summary Findings - Agriculture

Fifteen agricultural audit reports covering 21 projects are included in this review. The projects consist of eight agricultural credit operations, eight livestock development projects, three irrigation projects, and two settlement projects. [Agriculture was chosen for this extract as one example of the sector reviews in the original report.]

Objectives and strategy. The major objective of the projects was to increase agricultural production, mainly through intensification. Twelve projects sought to increase production on almost the same land area; seven others supported a mixed strategy, including both expansion in area and increased production on existing area. The most common means employed was to finance on-farm and on-ranch development, frequently supplemented by technical assistance to ranchers and farmers. Other methods included mechanization, increased use of fertilizers and improved seeds, increased and more reliable availability of water, and the settlement of new lands. In addition to project objectives, six projects also called for adjustments in sector policies. In one case producer prices for beef and dairy products had to be improved; in another, the incentives for beef producers needed to be increased. One of the major objectives of two projects in Latin America was to move from subsidized to commercial interest rates. Two projects in East Asia called for water charges to be set so as to fully recover the operating and maintenance costs.

Seven of the 21 operations were carried out by agencies which already had experience of previous Bank-financed projects; seven by new agencies especially established for the purpose, three by existing institutions with no previous experience of Bank operations, and four by newly established banks in the countries concerned. The most innovative ones were three projects in Africa. One of these was the first undertaken by the Bank in support of a national development program based on collective concepts, and involving a large Bank loan for cooperatives. It was also one of the first projects whose primary beneficiaries were to be subsistence farmers and landless rural workers. The second project included an innovative scheme of intensive technical assistance to small farmers. The third project attempted to increase beef production, particularly by tradi-

tional pastoral societies, at a time when many experts were skeptical about the future of African livestock systems. As it happened, these were also projects that ran into major difficulties in implementation. On the other hand, nine projects were repeaters of previous Bank projects. Whether the lessons of earlier projects were reflected in these nine is discussed later.

Implementation: costs and timing. Eleven of the 18 projects on which full data were available were completed either without cost overruns or with overruns of less than 10%, while four had overruns of about 30%. Some credit projects had to be reduced in scope to avoid cost overruns. In two of the 30% overrun cases, higher prices and additional work accounted for the increase; in one project a dam had to be increased in size, and in another additional repair and improvement works were carried out. In the remaining two cases, the costs of purchase of livestock were substantially underestimated as were the costs of maintaining previously planted orchards. Some of the other projects appear to have had costs much lower than estimated; these were not completed as planned. Of the 18 projects which were completed, 12 show an average delay of only about 10% over the time originally estimated. Efficient project management appears to have been the main factor behind timely implementation in these cases. The remaining six projects suffered substantially longer delays averaging 50% of the original estimate.

In one case, the cooperative program that the project was intended to support turned out to be too large and complex to be efficiently administered. Political difficulties also contributed to the delays in getting the project started and by 1970, after some three years had elapsed, the government revised the entire agricultural cooperative program and reduced the area to 30% of the original program. As a result $8.8 million of the original $18.0 million loan was cancelled, and the undisbursed balance ($3.1 million) was used for the revised smaller project which has achieved some measure of success. In a second case, the project encountered serious external difficulties: a succession of droughts, and a sharp increase in the price of fertilizer in relation to that of groundnuts. The project was substantially revised downward in 1970, by about one third. In a third case, the project encountered a number of serious technical, economic and managerial problems and the executing agency was soon in a difficult financial situation. The Bank and the government were unable to agree on how the project could be revised and eventually, by mutual agreement, the loan was cancelled. In a fourth case, a new government took office during the implementation period: it announced plans to lower insterest rates and make more long-term loans available for agricultural investment. These new policies conflicted with the project's approach of unsubsidized interest rates; demand for the project subloans collapsed; project implementation was suspended and the loan cancelled.

Project results: production. Fairly good information on areas, yields and production was available for most of the projects reviewed, and in most cases the targets for increases in areas and yields were achieved or surpassed. Of the 21 projects, 14 were carried out more or less as originally intended or better. In six projects the objectives for increases in area, yield or production as set out at appraisal were surpassed. These included two agriculture credit projects, two irrigation projects and two settlement projects. In two cases the area irrigated was larger than expected. In one case, production of palm fruit per hectare passed world records. In a fourth case yields increased more rapidly than projected.

Seven projects, however, did not achieve their original objectives for a number of reasons. These seven include four projects in which the loans were either wholly or partially cancelled. In two other cases the credits were disbursed but the expected results were not achieved. One livestock project involved complex organizational arrangements which did not work as intended. Another livestock project involved the development of state ranches, but owing to management problems the projected increase in production did not occur: the ranches never made an operating profit, since annual overhead expenses alone were regularly higher than the gross revenue from cattle sales. An agricultural credit project encountered severe external difficulties and had to be substantially scaled down. A few other projects revealed some shortcomings: in one, farm machinery financed by the credit remained underutilized; in another, the project may need further works in order to achieve the cropping targets set at appraisal. For three livestock projects, the later reports suggest that expectations at appraisal might have been overly optimistic.

Economic returns. The economic return on any proposed project at time of appraisal is derived from estimates of future costs and benefits. The return as calculated at the time of audit is also an estimate, although the basis of the estimate takes account of more recent data (the actual economic return on a project cannot be calculated until its life is over).

Ten out of the 21 agricultural projects reviewed show economic returns significantly above 10%, and all but one of these were in line with the estimates in the appraisal reports. One irrigation project showed marginally acceptable returns of around 10%. Three livestock projects were successfully implemented but suffered from an unforeseen decline in the price of beef, resulting in economic returns from pasture improvements in the range of 0% to 8%. Four projects encountered serious difficulties in implementation, and rates of return were all below 10%. One suffered both from unfavorable weather and adverse price changes; the return was therefore bound to be low even though prices have since recovered and the re-

duced project was completed with some degree of success. A second project also suffered from unfavorable prices. Implementation of the three other projects was not completed.

Beneficiaries, employment and income. There is no definite pattern regarding the types of farmers that the projects reviewed in this report attempt to serve. While nine of them were aimed at small farmers, eight were intended to serve medium and large farmers, and the remainder were for all types. Most of the projects actually reached the kind of farms or farmers they were supposed to. In four cases, farmers bigger than those planned were financed; in another case, smaller than planned; and in two cases, more big and small farmers were reached with a reduction in the share of the medium size farmers. Disregarding seven projects on which information is not available, more farmers than envisaged were served under this group of projects as a whole.

Only six reports present information or comment on employment and income, reflecting the fact that targets for employment and income were seldom included in Bank projects when this batch was prepared. On the basis of this small sample, a few summary comments are possible. Labor requirements per hectare underwent little change in one case. In another, total employment increased during Phase I and decreased during Phase III but the overall objective of retaining the pre-existing labor level seems to have been achieved. Total labor requirements increased in a Latin American project as a result of increases in both area and yields, while lack of secondary employment opportunities remains a problem in an East Asian one. As to incomes, average farmer income has increased above appraisal estimates in two, perhaps three, cases; it has increased faster than the average income of non-participating farmers in a fourth case.

Project results: institutional. At the institutional level, it is clear that the most successful projects were those which were carried out by experienced institutions. The fairly modest institutional improvements which were incorporated into projects worked successfully in two countries, but not in a third. In two countries new banks were successfully launched, although the objective of one was subsequently changed. On the other hand, the more ambitious attempts at institutional change all encountered serious problems. In one case, some of the measures taken eventually did achieve a degree of success--the management of the agricultural cooperatives has improved, many more qualified accountants and technicians are available and a Bureau of Controls has been set up. In a second case, the institutional framework was ill-defined from the start and it was difficult to secure the government's commitment to the major institution-building efforts required. Attempts were made to improve management, procedures and the accounting system of the ex-

ecuting agencies, and to improve their effectiveness, but the problems involved in changing government organizations and procedures to carry out new types of projects seem to have been underestimated. The situation has improved in some respects and a second project reflects the experience gained from the first. In one East African country, institutional objectives appear to have been similarly over-ambitious. The proliferation of administrative units placed an unnecessary burden on the limited national supply of qualified technicians, heightened tensions and created conflicts, delaying project implementation.

Six projects explicitly include training as a project component or as an element within a broader instituion-building component. In all cases, training was successfully implemented.

Summary Findings on Agricultural Projects

With hindsight, a few comments on project preparation may be useful. There were problems of design in at least two of the innovative projects. One was judged too ambitious and had to be subsequently scaled down. Whether a pilot project would have been possible in the circumstances then prevailing it is difficult to say. In the second case, project design could have benefited from greater flexibility and been presented more realistically. The project design failed to reflect the risks involved and conveyed a confidence that failed to alert subsequent supervision missions to difficulties. Among the other projects, one was institutionally over-structured. In another, it should have been possible to realize that the objectives were inconsistent with over-all government policies. The project should either have been re-designed or not put forward. The general conclusion is worth repeating: with risky and problem-prone projects (and the Bank, to its credit, dealt with many such projects), the potential risks should be clearly spelled out during project preparation and design. Bank practice now requires explicit discussion of risk for all projects.

A certain flexibility of design in innovative projects would be a natural inference from the experience described above. In the case of one complex project, forecasts were known to depend on risky assumptions about the capability of the government to implement it. Nevertheless, project design and subsequent supervision failed to take account of the pioneering nature of the project, or to present a continuing analysis of performance. Similar deficiencies of supervision were noted in another project. The point is that innovative projects, whose number is increasing, call for especially alert and frequent supervision. Flexibility in project design should assume such supervision (in fact it is already beginning to happen).

In agriculture, perhaps more than in other sectors, the national policy environment is crucial. The experience of a number of projects in this Review underlines the need for agreement between the Bank and the borrower on policy issues, especially when the Bank expects to be involved in a series of projects in the sector. It would be futile to count on the borrower's commitment to a project which does not fit this larger scheme of things.

Institutional change takes time and is probably most difficult to bring about in rural development or social sectors. Not only are institutional requirements for inter-disciplinary projects more complex, but the larger questions of sociological response and acceptability of change have also to be faced. It seems imperative, therefore, to approach institutional change gradually within the span of a series of projects. The institutional disappointments in the present Review might have been avoided or reduced if they had been approached more gradually. This would have also given more time for training local people and laying a data base for subsequent projects.

Follow-on projects. Most of the projects reviewed were followed by other Bank-financed projects; seven were continued with straightforward follow-ons. In four cases, similar activities were started elsewhere in the country. Sometimes but not always, the lessons learned from the projects under review were utilized to introduce improvements in the follow-on projects. Some notable positive examples are: an agricultural credit project in South Asia, in which the ongoing project was amended to reflect experience with subsequent credit projects; the trials and analyses being financed under an agricultural project in West Africa to permit a better assessment of the economics of the use of fertilizers; and the setting up of monitoring and evaluation units along with a more intensive approach to institution building in certain agricultural development projects in West Africa. By contrast, two "repeater" livestock projects in East Africa, both more complex and many times larger than the first ones, are examples of the negative. In one, the efforts to make the organization set up for the first project work were nullified when the organization, after finally being made to work, was changed. In the other case, the management problems encountered under the first project were not fully addressed in preparing the second project.

CONCLUSIONS

Most of the 70 projects reviewed here have been implemented successfully and are in operation, more than half with expenditures close to or less than appraisal estimates. Although many projects were changed during implementation, and took longer to complete and cost more than originally estimated, over 90% of the investments clearly remain worthwhile, with expected economic returns similar to or substantially better than those estimated at appraisal.

Only four of the 70 projects reviewed were not completed and the loans and credits for them were cancelled. Two of the cancellations of agricultural projects resulted from a change of government and its policies; a third encountered apparently unsurmountable technical, economic and managerial problems; and the fourth, a highway project, encountered comparably difficult problems and delay. Of the remaining 66 projects, their economic prospects remain satisfactory even after considering the delays in execution, cost overruns, and the host of problems encountered in achieving institutional objectives, although they would have been worth even more to the borrower had these problems been less severe. Only ten projects, comprising about 8% of the total investment by borrowers, yield estimated returns at audit that are either unsatisfactory or uncertain.

Three low-return utility projects are not included in this group of ten because the lower financial returns at audit reflect low rates rather than poor projects. The other lower than expected returns do represent real losses to borrowers, consisting of foregone gross benefits or increased costs; however, they do not all reflect poor investment decisions. The lower return for one highway project, for example, is partly due to unforeseen construction problems for a development road opening up a new area. The low return for a shipping project is attributable to the depressed state of the ship charter market following the large increase in world oil prices and not to a weakness in project design: these exogenous circumstances could not have been foreseen at the time of appraisal. A DFC project was affected by the country's division. The largest number of projects with low returns are found among the agricultural projects: eight of the eighteen projects completed show a prospect for returns of around 10% or less; three of these projects were implemented as planned and the low returns are the result of adverse changes in world market prices.

World price trends have contributed to protecting or improving the economics of many projects, especially in the power and transport sectors. Notwithstanding increasing capital costs, rising fuel prices have improved the attractiveness of highway projects by increasing the savings on vehicle operating costs, and the attractiveness of hydroelectric projects by increasing the costs of operating possible thermal alternatives. Some agricultural projects have also benefited by price movements, although others have been hurt by them. Price trends have adversely affected the financial performance of many utilities.

The concentration of the disappointments in agriculture appears to hold special significance, since the largest number of Bank/IDA operations are currently being undertaken in this sector. Each of the four agricultural projects with the least favorable prospect at

audit involves a substantial innovative element; each is the first of its kind in the country; three of them are the first of their kind for the Bank anywhere; and all are in Africa. Two involved considerable Bank effort in the development of institutional arrangements to carry them out; and all involved risks that some important aspect would not develop as planned. As previously stated, in many agricultural projects, unlike infrastructure, investment is only one of several important elements required for the successful operation of the project. The failure here lay in not clearly recognizing at appraisal the risk that these more complex projects might not develop as expected; in some cases the action proposed and the outlook presented at appraisal turned out, in retrospect, to have been based on less than full understanding of the local situation.

A number of projects failed in their institutional objectives due to insufficient understanding of local conditions on the part of those charged with their implementation. Institutional improvement, including training, is critical to the country's longer term development. The majority of projects include some element or the other of institutional change, yet some of the consultants who are entrusted with the task sometimes show little knowledge and understanding of local conditions. Failure is sometimes ascribed to inadequate support to the projects by local authorities, with some justification. More often the root cause is a failure, in the process of selecting consultants and drawing up their terms of reference and supervising their work in the initial stages, to ensure that there is adequate understanding of local conditions and suitable adaptation of the proposals to fit them. However, these cases are not typical of the projects reviewed.

Strategy and time horizon. Close to 75% of the projects in this review are either repeaters or have every expectation of being repeaters--so the time horizon over which a project's objectives are viewed becomes of paramount importance. A number of projects, which have traditionally been designed and subsequently evaluated as discrete units, have revealed a tendency to impose change from the outside, to force its pace, and to set high store by a large number of loan covenants. When all these covenants are not observed and change takes longer than projected, the project is sometimes judged as having failed in its objectives. But the more appropriate conclusion may be that the strategy of change and development, and the sequential programming of Bank operational objectives in the sector in that country, were imperfectly formulated. This conclusion is especially pertinent in sectors like agriculture and rural development and education which partake of social engineering, and where success often depends on a correct perception of behavioral patterns of large numbers of people and how best they could be affected. It also pertains to the wide spectrum of effort which goes under the name of institu-

tional development. An example of success in the present review is a Latin American country where, through a series of projects, the Bank has been successful in inducing significant improvement in the transport sector. By contrast, one could mention two innovative agricultural projects in Africa, both of which involved major institutional changes which were clearly over-ambitious in their immediate objectives. The flexibility in design of some recent agriculture and rural development projects is an evident response to this type of experience. But it does not reduce the continuing need for a well thought out program over time for pursuing national and sectoral development objectives through a sequence of individual projects.

This conclusion is reinforced by those completed projects which reveal a lack of complete understanding between the Bank and the borrower of what was sought, in the short term and in the long, and what were the borrower's obligations to provide a policy environment congenial to these objectives. The forging of effective links between discrete project goals and larger institutional or policy goals is inherently difficult, especially where the project agency is not responsible for these larger matters and may not even see itself as being vitally concerned with them. For example, policy on interest rates, which affect choice of technology in agriculture and industry and the ability of financial intermediaries to mobilize savings, constitutes one such recurrent project issue. Another is policy on user charges for public utility services and for irrigation water, which affect demand for service, enterprise finance, and public savings. Failure to agree fully on such larger project objectives entails a high risk of frustration and misunderstanding later, even where the more project-specific goals have been successfully achieved.

[Extracted from Annual Review of Project Performance Audit Results, World Bank, Washington, D.C., February 1978, pp. i-ii, 1-19, 42-46.]

The Development Impact of Private Voluntary Organizations

Development Alternatives, Inc.
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[The developmental impact of the many and variegated activities of private voluntary organizations in developing countries have seldom been evaluated on a comparative basis, and not with the systematic application of a uniform method to a wide range of projects. This article explores a way in which this could be done.]

This report presents findings from a field study of 17 private voluntary organizations (PVO) development projects in Kenya and Niger. The study was commissioned by the Office of Private and Voluntary Cooperation of the Agency for International Development (AID), with two principal objectives:

- To document evidence of developmental impact in PVO-assisted projects and identify the determinants of impact; and
- To test and develop a cost-effective methodology for documenting and explaining such impact within a comparative framework.

These concerns arose from a steady growth in AID's support to PVOs during the past five years, and an increasing demand inside and outside the Agency for evidence that development assistance is achieving its stated aims. In terms of policy, four critial questions need to be addressed:

- Are PVO activities resulting in development benefits?
- Are these benefits accruing primarily to the poorest members of the population in developing countries?

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- Will project benefits be sustained when PVO activities are phased out?

- Are PVO activities cost-effective in terms of potential spread and replicability?

Satisfactory answers to these questions require an empirical base of project-level data. This study, with its explicitly comparative thrust, is the first of its kind directed specifically at PVO projects. The 17 projects are briefly described in Figure 1.

The sample is relatively small, and expansion of the number of cases is both desireable and feasible with the methodology employed. Nonetheless, the two countries contain a wide range of projects, and present striking contrasts. They differ in the level of economic and infrastructure development (high in Kenya relative to Niger) and in the degree to which PVO activities are regulated by the government (much more closely in Niger than in Kenya). These contrasts help to illuminate and account for the observed differences in impact.

Framework and Findings

A straightforward conceptual model was used in this exploratory field study. To aid the collection and analysis of data, the concept of developmental impact was broken down into three dimensions:

1. Direct benefits generated by the commitment of PVO resources, standardized for differences in project costs;

2. The potential for continuation of these benefits after the donor's resources are exhausted or withdrawn; and

3. The prospects for future development in related activities by the same participant population, based upon the success of the present project.

These variables were categorized as direct benefits, benefit continuation and benefit growth, respectively. When given separate numerical scores, the sum of these scores would indicate the overall impact achieved by each project. In order to explain variation in impact, the most probable determinants were also specified, and treated as independent variables. These were grouped in two categories, PVO strategy variables and project environment variables.

A deliberate effort was made to select projects that PVO representatives themselves considered successful and sufficiently mature to yield evidence of impact on the intended beneficiaries. The resulting sample includes projects of the following types:

FIGURE 1: PVO PROJECT SAMPLE

Project	Full Name (Location*)	PVO Sponsors	Function
KENYA			
Bushiangala:	Bushiangala Harambee Water Project (Kakamega Dist., Western Prov.)	NOVIB (Netherlands), CARE/Kenya	Water pumped from stream, piped to school and 6 communal outlets
Interchurch:	Interchurch Seed Project, renamed Ukambani Integrated Rural Development Project (Eastern Prov.)	OXFAM, Salvation Army, National Christian Council of Kenya, Catholic Secretariat (Kenya)	Introduce improved agricultural practices through church groups
Kandara:	Kandara Water Scheme (Murang'a Dist., Central Prov.)	Ten Organizations**	Deliver piped water to ca. 30,000 rural households by gravity flow.
Katothya:	Katothya Harambee Water Project (Kitui Dist., Eastern Prov.)	CARE/Kenya	Year-round supply of water from rock catchment piped to 2 communal outlets.
Katyethoka:	Katyethoka Harambee Water Project (Kitui Dist., Eastern Prov.)	CARE/Kenya	Year-round supply of water from rock catchment piped to 3 communal outlets.
Kawangware:	Kawangware Human Development Project, (Nairobi)	Institute of Cultural Affairs (ICA)	Multi-faceted social and economic project, focus on employment and training.
Kyuso:	Kyuso Agricultural Improvement Scheme (Kitui Dist., Eastern Prov.)	Catholic Relief Services, OXFAM	Promotion of agricultural technology: oxplow purchase, tractor hire.
Maseno South:	Diocese of Maseno South Rural Development Project (Nyanza Prov.)	E.Z.E. (W. Germany), National Christian Council of Kenya	Form church and parish level committees to promote health care and agricultural change.
REES/RMLS:	Rural Enterprise Extension Service and Rural Market Loan Scheme (Western Prov.)	Partnership for Productivity (PFP), PACT, UMCOR, National Christian Council of Kenya	Small business advisory service with management training and experience in the use and repayment of small loans.
NIGER			
CDARMA:	Center for Development of Rural Artisanry and Agricultural Machinery (Dosso Dept.)	Euro Action-Acord	Retain traditional blacksmiths to produce and repair animal traction equipment.
Liboré:	Liboré Livestock Fattening Project (30 km. south of Niamey)	Euro Action-Acord	Promote cattle fattening by small farmers as source of income, while improving meat supply.
Maggia:	Maggia Valley Reforestation Project (Bouza Arrond, Tahoua Dept.)	CARE/Niger	Tree planting for windbreaks to protect agricultural land.
Talak:	Project for the Development of the Talak Plain (Arlit Arrond., Agadès Dept.)	*Routes du Monde* (France), CARITAS/Niger	Construct a dam and dike system for using seasonal floods to create new pastures in an arid area.
Oasis Air:	Project Oasis Air (Tabelot area, Agadès Dept.)	Church World Service, Lutheran World Relief	Improve marketing opportunities and enhance productivity in an area of small-scale irrigated agriculture.
SIM/MARADI:	Sudan Interior Mission Rural Development Program (Guiden Roumji Arrond., Maradi Dept.)	Sudan Interior Mission	Establish woodlots, promote improved agricultural techniques and implements in four villages.
Tchin Tabisgine:	Project Tchin Tabisgine (Agadès Dept.)	EIRENE (West Germany), Lutheran World Relief	Introduce irrigated oasis gardening, reconstitute livestock herds for drought-affected population.
Telemces:	Telemces Area Project, (Tchin Tabaraden Arrond., Tahoua Dept.)	Lutheran World Relief	Improve agricultural productivity, particularly market gardening; dig wells; improve road access to isolated area.

* Locational abbreviations: Dist. = District, Prov. = Province, Arround. = Arroundissement, Dept. = Department.
** Misereor, German Hunger Committee, E.Z.E. (W. Germany); NOVIB, Bishops' Lenten Campaign (Netherlands); CAFOD (U.K.); Canadian Hunger Foundation; Australia Freedom from Hunger; American Hunger Foundation; CARE/Kenya

- Four self-help rural water projects (all in Kenya);
- Seven rural development projects emphasizing agricultural productivity (three in Kenya and four in Niger);
- Four projects with a training thrust and a focus on income generation (two in Kenya and two in Niger); and
- Two projects using community labor for conservation of the natural and economic resource base (both in Niger).

Direct benefits. The direct benefits of projects in the sample were estimated on the basis of field data which were standardized for purposes of comparison. The results computed for direct project benefits, project costs, and the relationship between the two for the Kenya projects are presented in Figure 2. [Niger omitted for brevity.] The first column refers to benefits "in kind," not all of which are quantifiable. As a result the "monetized benefits" in the fourth column refer to some, but not necessarily all, of the "in kind" benefits listed in the first; they are the benefits which can reasonably be given a money value.

Column (2) shows the number of direct beneficiaries for each project; benefits and costs are compared among projects by obtaining values per household of participating beneficiaries. The level of precision in data collection varied widely with this indicator. At Katothya, for example, it was recognized that the number of persons collecting water from the project site, almost all of them women, would fluctuate on a seasonal basis. Maps, census records, physical observations (including counts of those collecting water during certain times of the day during field visits) and interview responses were drawn on to estimate the level of use. The number of beneficiaries for the water projects was calculated assuming completion of the project (projects were in varying degrees of completion). For purposes of comparability the household was taken as the standard unit. For the Kenya projects, mainly situated in sedentary farming areas, it was assumed that the average household contained six persons; for several of the Niger projects household numbers were already known, and in others an average size of eight was assumed. Indirect beneficiaries were not included in the calculations, although in a few cases there was some basis for attributing secondary benefits to the project itself. In order to be consistent, however, the results refer only to the benefits directly traceable to each project, and to decisions made as part of its activities.

Column (3) shows the degree of verification obtained for the linkage between project services and imputed benefits, which varies

FIGURE 2

DIRECT BENEFIT: KENYA PROJECTS

	(1) Benefits in Kind	(2) Direct Beneficiaries	(3) Verification Level	(4) Value ($) Benefits/ Participant Per Year	(5) Annual Recurring Cost Per Participant	(6) Project Cost Per Participant to Date	(7) Ratio Net Benefits (4-5) to Cost (6)
Bushiangala	a. More potable water b. Time saving (women) c. Better health	750 households	Moderate	$ 69	$ 4	$ 52	1.25
Kandara	a. More potable water b. Time saving (women) c. Improved agricultural yields/ income d. Better health	30,000 households	Strong	$152	$ 31	$239	0.51
Katothya	a. More potable water b. Time saving (women) c. Better health	400 households	Moderate	$ 23	$ 1	$ 29	0.76
Katyethoka	a. More potable water b. Time saving (women) c. Better health	400 households	Moderate	$ 23	$ 1	$ 31	0.71
Interchurch	a. Higher agricultural yields b. More farmer income c. Drought-resistant crops	1,960 households	Weak	$ 10	$ 3	$ 9	0.78
Maseno South	a. Agricultural inputs b. Agricultural credit for inputs c. Higher yields d. More farmer income e. Cheaper/available medicines	3,000 households	Moderate	$ 15	$ 9	$ 49	0.14
Kyuso	a. Ox-plows/training b. Tractor plowing c. More acreage in production d. Higher yields e. More farmer income	540 households	Strong	$186	24	$ 69	2.35
REES/IRTS	a. Improved management practices b. Higher profitability c. Credit to expand business	370 clients	Weak	$141	$359	$1,243	(-)
Kawangware	a. Adult skill formation b. New employment created c. Greater access to education	240 trainees	Weak	$126	$100	$554	.05

widely. At Kyuso, for example, farmers participating in the tractor hire scheme and/or the ox-plow loan-purchase scheme confirmed that they had been able to cultivate larger acreages and had experienced higher yields per acre, and were specific in citing amounts, so that the service-to-benefit linkage was comparatively simple to verify. At Kandara, the linkage was directly visible in observed uses of water for dairy animals and domestic consumption. In other cases, however, there were a variety of problems, including: 1.) Difficulty in translating total membership of groups into reliable adoption rates for recommended techniques whose beneficial effects are demonstrable (a problem that arose with Interchurch); 2.) Disparity between the numbers of people enrolled in training programs at Kawangware, and numbers actually placed in productive employment; and 3.) Lack of a basis for correlating an observed benefit (increased profitability in a sample of 49 REES clients' businesses, which may or may not differentiate them from non-clients) with responsiveness to project consultants' advisory service.

Benefits in relation to project costs. The monetized benefits shown in Column (4) reflect the magnitude of benefits directly realized by project participants, minus any compulsory charges that participants incur directly. Costs or charges that are routinely paid "out-of-pocket"--such as the amount paid (in cash) by Kyuso farmers to hire the project tractor--have been deducted. But costs borne by the project which are not but could be made payable by participants--wuch as the subsidy needed to cover the remaining tractor running costs and depreciation not covered by amounts charged to farmers--have been omitted; these are shown separately in Column (5). The figures in Column (4) reflect weighted averages in those cases where direct beneficiaries fell into more than one category. For SIM/Maradi, for example, the figure of $137 represents such an average, since 120 households were benefiting from the wood-lot component of the project ($40/household/year) and only 50 were participating in the agricultural activities ($233/household/year).

The annual recurring costs are shown in Column (5). In those cases where a revolving fund had been established by the PVO or another donor, the fund was considered as a "sunk cost" within the project and was excluded from the recurring costs. This distinction applied to Maseno South, Kyuso, Liboré and CDARMA, among others. In general the four projects with a skill formation/training thrust (Kawangware, FEES/RMLS, Liboré and CDRAMA) ranked high in their annual requirements per participant. In contrast, three of the water projects in Kenya (Bushiangala, Katothya and Katyethoka) and the two environmental restoration projects in Niger (Maggia and Talak) were designed to be virtually maintenance-free.

Column (6) in each figure shows the total project cost to date financed from external sources, in dollars per participant. This

indicator refers only to resources from outside the benefiting community; host country government contributions were included, as well as those made by PVOs and other foreign donor organizations. For the four self-help water projects in Kenya, for example, contributions of cash and labor made on a *Harambee* (self help) basis have been excluded.

Column (7) shows the ratio of the annual net benefit per participant (direct benefits minus all recurring costs) to the external project cost. Due to the nature of the data this indicator is hardly precise to the second decimal point, but it serves to show the relative capacities of projects in the sample to return their costs. The inverse of this ratio would indicate the number of years required for the project to deliver sufficient net benefits to repay the investment of external resources. The variation is extreme, with Kyuso requiring less than half a year and REES/RMLS never repaying the investment because of negative annual net benefits. Sensitivity analysis was used to test the effects of seriously underestimating benefits in the weaker projects; their rank order with respect to this indicator did not change significantly.

Benefit continuation. The judgments arrived at in estimating continuity are essentially predictive, in that they attempt to gauge the probability that the benefits provided to participants will still be attainable when external resources--specifically, those supplied by the PVO--are exhausted or withdrawn. Since the collection of data took place at a single point in time, these forecasts are stated with a degree of caution--in particular, assessments of the capacity of local-level leadership. It is implicitly assumed that the balance of factors in each local situation is stable, since a full understanding of the socio-political dynamics in each community could not be acquired in the time available. The underlying hypothesis is that projects with a strong participatory content stand the best chance of sustaining their impact over at least the medium term, i.e., beyond the duration of donor support. This proposition is central to the rhetoric and philosophical orientation of almost all PVOs active in the field of development, but it is usually treated in abstract rather than concrete terms, so that comparisons between projects are difficult to make. The indicators used here deliberately narrow the definition of the term to facilitate comparisons.

The first indicator, strength of local organizations in decision making, deals with the evidence of a capability within the participant group to assume major responsibility for managing the activities associated with the project. It was assumed that the existence of a "project committee" per se was less instructive than the range and complexity of functions undertaken by it, and its frequency of interaction with project participants. Similarly, in assessing the

quality of local-level leadership, consideration was given to the roles of key individuals in the interface with external agents (both PVO and government), and the relationship between local leadership within the project and the patterns of authority and influence in the surrounding community. The range in scores was from 0 to 3 for this indicator, with zero indicating no local organization of participants.

The main concern of the second indicator, resource commitment, is with the level and amount of resources which participants have committed to project activities. There were two types of project with different kinds of resource demands on beneficiaries: projects in which provision of continuing services depends on a budget requiring annual expenditure for salaries, materials, inputs, etc.; and projects consisting mainly of light infrastructure or public works, in which the main costs arise during the construction phase.

It is apparent that none of the projects with annual budgets is presently "paying for itself," i.e., raising enough funds from participants to cover all operating costs. Kyuso (Kenya) and Liboré (Niger) had advanced furthest towards this status, and in both projects financial self-sufficiency is an explicit goal of the staff currently in control of management. Several projects in Niger in which a formal subsidy existed may be taken over by the host country government; the possibilities appear strongest at Oasis Aïr and Telemces. Here the burden of paying for all project-supplied services may not fall on the participant group. Among the light infrastructure projects, the four Kenyan water projects based on *Harambee* contributions of costs, labor and materials from the beneficiary community contrast rather sharply with the two examples from Niger, Maggia and Talak. The provision of PVO support to the Kenyan *Harambee* projects had been made conditional on firm evidence of local resource commitment: PVO resources would have gone to other, more "deserving" projects if community donations to the projects had not occurred. At Maggia, on the other hand, food-for-work rations have been distributed each year by CARE to all male villagers who participate in tree planting. It is open to question--and villagers did not agree on this subject during interviews--whether sufficient labor would have been available if requested on a purely voluntary basis. At Talak, the prospects for enlisting voluntary contributions were complicated by several factors. In the especially severe post-drought circumstances, most households lacked any means of subsistence and needed wages from manual labor to rebuild their herds; and the radical nature of the transformation proposed through seasonal flood control was not well understood by the local population. For these reasons it proved impracticable to insist on voluntary labor, so that tangible proof of local commitment to the project is lacking.

The third indicator of benefit continuation is the adequacy of mechanisms for mobilizing resources; the scoring represents different levels of certainty. The main question concerns the demonstrated capacity for resource mobilization relative to the potential demands posed by the project. Thus projects with fairly high resource demands may score either high (e.g., Bushiangala, whose water committee has already begun collecting money from users), or low (e.g., REES/RMLS , where there is scant possibility that client businessmen would ever agree or be able to pay all costs). For example low-demand projects like Maggia and Talak were designed to be virtually maintenance-free; yet, there is no certainty that the modest inputs of manual labor, required on an occasion basis, could be mobilized without some external stimulus.

Benefit growth. The model of development adopted in this study demands that one look beyond the immediate context of project activities. The discussion of benefit continuation focused on parameters used to assess the probability that existing direct benefits would be maintained after the nominal lifetime of the project. This section on benefit growth potential considers the likelihood that project outputs can lead to a diversification of development benefits beyond those in the original scope of the project. The observations were limited, however, to the participant group involved with the project itself, thereby excluding possible effects in adjoining areas. [Note: The question of project replicability is not addressed in this variable.]

Benefit growth in this sense may be realized in a number of different ways. Some PVO-supported projects consciously attempt to ensure such growth by providing a training function as part of the project design. In such cases it is assumed that participants will not only be able to use their training in project activities but also to seek out and take advantage of new outside opportunities.

Within the present sample, 11 projects had significant training components, while in six little or no resources were devoted to training. For example, the Interchurch and REES/RMLS projects (Kenya) have been carried out primarily as educational ventures. In the Interchurch Project the major effort was to establish demonstration plots where farmers can see and test new techniques that they can apply to their own farms. The integration of such recommendations into local farming practices would assure that they would continue beyond the lifetime of the project, and the experimental nature of the demonstration process encourages farmers to try out and assess other techniques that might be introduced in the future. In a similar fashion the REES effort attempts to teach businesspersons a set of techniques that they can utilize on their own, eventually without the aid of a REES consultant. The other com-

ponent, RMLS, gives them the opportunity to take advantage of small loans and to develop an experience and a record that could be utilized in applying for future loans from conventional sources. None of the six "infrastructure" projects in the sample, on the other hand, has incorporated a specific training function. In the four Kenyan water projects, the provision of a new source of water would seem to offer an excellent opportunity for promoting improved health practices, but no such effort has been formally undertaken. Similarly, the Maggia and Talak projects in Niger have not sought to promote specific practices related to reforestation or pasture maintenance respectively. Providing an educational component within a project does not, of course, necessarily contribute to future benefit growth; the recommended practices must be adopted by project participants. There is a considerable range, both in the extent to which new practices have been adopted and in the efforts made by the various projects to measure the rate of adoption, and they have been given scores reflecting such differences (i.e., the first indicator).

Another way of assessing benefit growth is to ask what improvements or investments individuals have made in their own farms, households or enterprises since the beginning of the project (indicator No. 2). It is often difficult to pinpoint explicit changes in behavior that are directly attributable to the project, but some clear examples appear within this sample. One such case is in Kandara, where the availability of water has led to several changes that will likely contribute to benefit growth. Because water is now piped to individual households, the supply is sufficient to support a dairy cow, and many households have already invested in these animals. Beyond this, water storage tanks are beginning to appear, and these will be used for such things as irrigating vegetable gardens. In the case of REES, data gathered on a sample of 49 clients indicated that 59 percent of profits had been reinvested in the small enterprises concerned, a practice with a potential for extra growth. At Kyuso, farmers participating in the plowing scheme were able to increase the size of their fields, and were hiring labor to help with the extra weeding. At Bushiangala and Maseno, some project participants had committed labor to household or farm improvements as well, although no significant cash investments of this kind were observed. Projects were scored on these farm or household improvements.

Beyond individual household investments, a project may serve as a catalyst for developing new community organizations or strengthening existing ones so that they can perform functions beyond those which constitute the specific project goals. The scoring system reflects the weight given to such new activities which appear to be ongoing and to have a strong organizational base in the community (indicator No.3). In some instances the expansion of community

efforts may be planned: for example, at Kyuso, the cooperative formed initially to regulate tractor usage has begun to assume other functions, as originally envisioned by the Catholic missionary who initiated the project. More often, however, this dimension of benefit growth appears to be relatively spontaneous, as at Katothya, where the increased water supply allowed the local school committee to plan for the construction of a new brick primary school. At Bushiangala and Kandara the water projects have each led to the development of several other organizations. The findings from the Niger subsample show comparatively lower scores for this indicator: only three projects had stimulated new activities, and all appeared to be of a temporary nature. Here the broad contrasts between the two countries--specifically, the absence of a counterpart in Niger to the *Harambee* phenomenon of self-help in Kenya--place the differences in perspective.

Impact summary. Figure 3 summarizes the developmental impact of the 17 projects in the sample. The first and second columns show the monetized direct benefits of each project and the level of verification obtained. Column (3) presents the benefit-cost ratios as computed in Figure 2, and this indicator forms the basis for the rank order in Figure 3: Kyuso ranks highest at 2.35, and REES/RMLS lowest with a negative ratio. It is important to note that high benefit/cost ratios were not consistently correlated with a high level of monetized direct benefits. Indeed, the highest amount per participant ($1,308 at CDARMA) was recorded in the second lowest instance of cost-effectiveness; and none of the eight highest-ranking projects generated over $200 in monetized benefits.

Interesting questions arise when the three scores on dependent variables are examined side by side, in columns (4) to (6). The projects ranking high in terms of direct benefit/cost did not necessarily have high scores for benefit continuation and benefit growth. For Interchurch, Katothya, SIM/Maradi and Katyethoka, the results indicate only low to moderate potential that the benefits delivered will be sustained and/or grow after the termination of the project. Conversely, Kandara and Liboré showed better results for the second and third dependent variables than for the first.

In order to develop overall categories of relative impact, the scores for direct benefits/costs, benefit continuation and benefit growth have been added in column (7). The scoring system for each variable had a range from 0 to 9 (these were three indicators each, with 0 to 3 scores, for the benefit continuation and benefit growth variables), so the maximum score for overall impact would be 27 and the minimum would be 0. The overall scores fall into three distinct groups:

FIGURE 3

DEVELOPMENTAL IMPACT SUMMARY

Project [(K) = Kenya, (N) = Niger]	(1) Direct Monetized Benefits	(2) Verification Level	(3) Benefit to Cost Ratio	(4) Benefit/ Cost Score	(5) Benefit Continuation Score	(6) Benefit Growth Score	(7) Overall Impact Score
Kyuso (K)	$ 186	Strong	2.35	9	6	6	21 High
Bushiangala (K)	$ 69	Moderate	1.25	9	8	4	21 High
Interchurch (K)	$ 10	Weak	0.78	8	3	3	14 Moderate
Katothya (K)	$ 23	Moderate	0.76	8	4	1	13 Moderate
SIM/Maradi (N)	$ 137	Weak	0.72	8	3	3	14 Moderate
Katyethoka (K)	$ 23	Moderate	0.71	8	4	0	12 Moderate
Telemces (N)	$ 159	Moderate	0.67	7	4	4	15 Moderate
Kandara (K)	$ 152	Strong	0.51	6	8	6	20 High
Oasis Air (N)	$ 459	Moderate	0.38	4	5	4	13 Moderate
Maseno (K)	$ 16	Moderate	0.14	2	5	4	11 Moderate
Liboré (N)	$ 114	Strong	0.10	1	6	5	12 Moderate
Talak (N)	$ 200	Moderate	0.08	1	1	1	3 Marginal
Tchin Tabisgine (N)	$ 197	Moderate	0.08	1	3	3	7 Marginal
Maggia (N)	$ 30	Weak	0.05	1	2	1	4 Marginal
Kawangware (K)	$ 126	Weak	0.05	1	2	2	5 Marginal
CDARMA (N)	$1,308	Strong	0.03	1	3	4	8 Marginal
REES/RMLS (K)	$ 141	Weak	(-)	0	2	6	8 Marginal

- Projects with high impact, scoring 20-21 (Kyuso, Bushiangala and Kandara, all in Kenya);

- Projects with moderate impact, scoring between 11 and 15 (Telemces, SIM/Maradi, Oasis Air and Liboré in Niger; and Interchurch, Katothya, Katyethoka and Maseno South in Kenya);

- Projects with marginal impact, scoring 3 to 8 (Talak, CDARMA, Maggia and Tchin Tabisgine in Niger; Kawangware and REES/RMLS in Kenya).

These categories reflect differences within the sample. Significantly, there are no borderline cases.

One obvious point is that none of the eight Niger projects appear in the high-impact category, reflecting the fact that none scored higher than 6 for benefit continuation or 5 for benefit growth. A related issue is the incidence of much higher external costs per participant in the Niger projects, which tended to reduce the index of benefits/cost as well. These results suggest two possible explanations: either PVOs operating in Niger must settle for less impact than can be achieved in Kenya due to environmental constraints; or it is the differences in the strategies and approaches of PVOs themselves that account for most of the variation in impact.

Possible Determinants of Impact

In the search for independent variables that might determine or influence the level of impact achieved in a PVO project, there are several possible ways to proceed. One method would be simply to ask what the projects in each category of impact (high, moderate, marginal) had in common. While this approach would offer some useful insights, it focuses too much attention on project-specific features in a small sample, rather than on the broader program and policy questions that motivated this study. One obvious possibility for affecting the level of impact is the magnitude of the external expenditure per participant in a PVO-assisted project. Figure 4 shows, however, that no fully consistent pattern emerges when this yardstick is applied. The relatively high-cost projects such as REES/RMLS and Kawangware were found to have marginal impact, while many of the high ranking projects were low in cost. But impact was not inversely related to PVO investment, since several of the more successful projects, such as Kandara and Oasis Air, were among the more ambitious and costly of those in the sample.

Another possibility would be to look for a relationship between the type of activity undertaken (i.e., project function, such as rural

water supply) and the level of impact. There is some evidence of this, as Figure 4 indicates: the water projects are evenly split between "high" and "moderate" impact; the agriculture/rural development projects are spread through all three categories but cluster at the "moderate" level; the skill formation/training projects are either "moderate" or "marginal," and both the environmental restoration projects are in the "marginal" category. This pattern is suggestive; but it reflects on the four functional types included in this sample, whereas PVOs are also involved in many other types of development projects.

PVO strategy variables. The information collected from PVO staff and representatives was used to define the policy and approach adopted by PVOs in the identification, design and implementation of each project. A review of the full sample then led to a classifi-

FIGURE 4

OVERALL IMPACT AS RELATED TO COST AND TYPE OF PROJECT

Level of Overall Impact	Score	Project [(K) = Kenya, (N) = Niger]	Total Cost Per Participant	Function
HIGH	21	Kyuso (K)	$ 69	Agriculture/rural development
	21	Bushiangala (K)	$ 52	Rural water supply
	20	Kandara (K)	$ 239	Rural water supply
MODERATE	15	Telemces (N)	$ 119	Agriculture/rural development
	14	Interchurch (K)	$ 9	Agriculture/rural development
	14	SIM/Maradi (N)	$ 155	Agriculture/rural development
	13	Oasis Aïr (N)	$ 951	Agriculture/rural development
	13	Katothya (K)	$ 29	Rural water supply
	12	Liboré (N)	$ 554	Skill formation/training
	12	Katyethoka (K)	$ 31	Rural water supply
	11	Maseno (K)	$ 49	Agriculture/rural development
MARGINAL	8	CDARVA (N)	$9,033	Skill formation/training
	8	REES/RMLS (K)	$1,243	Skill formation/training
	7	Tchin Tabisgine (N)	$1,114	Agriculture/rural development
	5	Kawangware (K)	$ 554	Skill formation/training
	4	Maggia (N)	$ 567	Environmental restoration
	3	Talak (N)	$2,617	Environmental resotration

cation of four distinct modes of PVO involvement in specific projects. These modes, referred to hereafter as "PVO strategies," encompass both the philosophy and the priorities of the PVO, and the ways in which these have been applied in the evolution of the project (these strategies will be referred to frequently by number). Strategy 1: Supplementing a specific community project that is based on self-help, with funds for materials and/or equipment (utilized for all four of the Kenya water projects, Bushiangala, Kandara, Katothya and Katyethoka); Strategy 2: Low profile-support to a project that depends on small groups at the local level to carry out activities and make key decisions (used in six of the agriculture/rural development projects, all but Tchin Tabisgine); Strategy 3: Major commitment of technical assistance, and a high degree of PVO involvement in defining and directing project activities (exemplified in the sample by REES/RMLS, Kawangware, Tchin Tabisgine and Talak); and Strategy 4: Financial and technical support to a project initiated and carried out by the host country government (exemplified by Maggia, CDARMA and Liboré).

In cases where Strategy 1 is employed, the PVO has no direct role in the origination or design of the project, and generally avoids assuming responsibility for its ongoing support. Thus, specific community projects that involve construction or repair of a facility--a finite set of tasks, for which resource needs are clearly spelled out--are well suited to PVO participation on these terms. And in a situation where there is a large number of potential "candidate" projects, as in Kenya, the PVO may be able to insist on a certain level of local contributions before agreeing to commit its own resources to a project.

The projects where Strategy 2 has been employed are concerned with rural development, and specifically with improving agricultural productivity. What distinguishes them from other cases in the sample is their reliance on local-level groups as the medium for project activities, with PVO personnel maintaining a relatively low profile. Of the six, Kyuso and Oasis Air have moved furthest towards instituting formal organizations (in both cases, a cooperative society) to oversee project activities. Telemces may follow the same course as the project evolves further. The other three projects (Interchurch, Maseno and SIM/Maradi) are comparatively unstructured and are highly decentralized as a matter of policy. The PVOs utilizing Strategy 2 have had a major influence on the origination of the project, because their field staff have worked with participating groups that are often affiliated in one way or another with an organized church. But decisions on the content of activities have generally been left to the groups themselves. Another feature of this strategy is the small size of project staff (PVO personnel or others) relative to the number of intended beneficiaries.

The projects concerned, with the exception of SIM/Maradi (limited to four villages), are ambitious in their attempted geographical coverage.

A common characteristic in Strategy 3 is the critical importance of PVO personnel in identifying, developing and implementing a large and costly project. In all four cases from the sample, it is reasonable to suppose that the project and most of its components would not exist without the impetus of the PVO's presence. This is reflected in the relatively heavy involvement of expatriate technicians (e.g., Talak, and until recently Tchin Tabisgine) in staffing and management of the project; even if expatriates give way to local staff as the latter gain appropriate skills and experience (e.g., REES/RMLS and Kawangware), the PVO remains responsible for obtaining financial support for the project. Relatively speaking, the four projects employing Strategy 3 are "high-risk" projects, not necessarily on technical grounds but in terms of the PVO's visibility and potential accountability for results.

None of the Kenya projects were initiated by the host government (i.e., Strategy 4), but three in Niger were developed along these lines. In each case the PVO took on a project proposed by the government whose design was essentially complete. Formally, at least, the role of the PVO is to supply resources, mainly funds, but sometimes including technical assistance (as at CDARMA and Liboré), to enable government services to execute the project. Nigerien officials have often been quoted as saying, *"il ne nous manque que le moyen"* ("we only lack the means"), implying that assistance from PVOs or larger donors need involve no more than paying the bills for particular projects. Recent policy directives indicated that the Government of Niger views Strategy 4 as the most appropriate mode of PVO involvement in the development process. In practical terms, however, the involvement of the PVO in implementation can go far beyond merely writing a check to cover project expenses. In both CDARMA and Liboré, technicians from Euro Action Acord have been present as project managers, and have been active in shaping the direction of the project. In the Maggia Valley Reforestation Project, CARE's role is more restricted.

Strategies and outcomes. When the four strategies are matched against the levels of impact, some interesting contracts appear. Figure 5 shows that Strategies 1 and 2 were associated with high or moderate impact, whereas Strategy 3 was associated with marginal impact and Strategy 4 with marginal impact in two cases and moderate impact in one. The same general approach did not always generate comparable impact, but a fairly clear distinction appears between the larger impact of Strategies 1 and 2 on the one hand, and lesser results from 3 and 4 on the other.

FIGURE 5

OUTCOMES OF PVO STRATEGIES IN SAMPLE

Level of Impact Achieved	TYPE OF PVO STRATEGY EMPLOYED			
	(1) "Top-Off" Local Self-Help Effort	(2) Assist Small Local Groups	(3) High PVO Profile/ Technical Assistance	(4) Support Government-Managed Project
HIGH (Total score 19-27)	Bushiangala (K) Kandara (K)	Kyuso (K)		
MODERATE (Total score 10-18)	Katothya (K) Katyethoka (K)	Tolembeo (N) Interchurch (K) SIM/Maradi (N) Oasis Aïr (N) Maseno (K)		Liboré (N)
MARGINAL (Total score 1-9)			RUDS/RVLS (K) Tchin Tabisgine (N) Kawahgware (K) Talak (N)	CDARMA (N) Maggia (N)

The direct benefit/cost score was high in all cases of Strategy 1 (the Kenya water supply projects), but important differences emerged in relation to the dimensions of benefit continuation and benefit growth. At Kandara and Bushiangala, high impact in all three dimensions was achieved when PVOs "topped off" well organized local *Harambee* efforts. A similar mode of assitance in the two other water projects (Katothya and Katyethoka) led to appreciable direct benefits, but a score of only 4 for benefit continuation and scores of 1 and 0, respectively, for benefit growth. Not only were the latter two projects very small in scale, but they were situated in a resource-poor area with a weak organizational base, and very little ongoing, complementary development activity. The data indicate that the topping-off strategy cannot by itself generate a broadly based process of developmental change. The expectations for this strategy must necessarily be modest, since Bushiangala and especially Kandara appear to be unusually favorable settings for self-sustaining development. There is no contemporary parallel in Niger to the Kenyan *Harambee* movement, and self-help projects are hardly ever begun spontaneously at the community level, so that a strategy in which the PVO waits for local initiatives is simply not applicable in Niger.

Generating impact: an overview. If the more successful projects in the sample including those in the "moderate" impact category are

examined as a whole, certain common characteristics appear in the process of project development. These characteristics, which are not synonymous with the elements defining strategy types, appear in greater or lesser degree among those projects that scored well for all three impact variables: 1.) Identification of a technology that is immediately applicable under local constraints, with a direct return to those who adopt it; 2.) An explicit effort to gain the widest possible commitment to the proposed intervention from prospective users before it is introduced on a broad scale; 3.) A deliberate attempt to draw on local capacities for self-help, whether latent or already firmly established; 4.) A policy of working through the formal administrative structure and the indigenous system of authority, in order to maximize access to the population of intended beneficiaries; and 5.) A demonstrated capacity to modify project content, dropping those interventions that do not take root, as implementation proceeds. While these do not constitute a complete formula for generating impact--for one thing, they must be translated into concrete terms applicable to the immediate project environment--they indicate key steps in the process through which the more successful projects evolved to their current state.

In its purest form, Strategy 1 fits these requirements very neatly: decisionmaking is decentralized, and the PVO merely awaits the outcome of the process at the community level. Much depends, of course, on how well the project formulation and resource mobilization operate within the community; this strategy necessarily reduces the possibility of the PVO improving the content of locally-generated projects.

Strategy 2 contains the greatest latitude for executing the five steps, precisely because it is the least structured of the four. In its purest form, the approach depends on local-level support for the intervention and evidence of self-help in the participating groups; without these, nothing of any substance will happen. Among the projects in the sample that utilized Strategy 2, the process was not followed through with equal vigor and imagination in all cases. The strategy demands creativity and patience by the PVO in almost equal amounts: even in unpromising environments, such as Kyuso's, these can generate very impressive results.

At first glance, Strategy 3 also seems perfectly consistent with the process outlined above. On a rhetorical level, and in terms of the broad philosophy of development assistance, the organizations concerned would have no difficulty in endorsing it. But in operational terms, the process demands great PVO flexibility, and a devolution of decisionmaking about project content and direction that is difficult to reconcile with Strategy 3. In the projects observed, the continuation of project activities never hinged on

participants' willingness to support them with the resources at their disposal. Had this been the case, it is doubtful that an adequate commitment would have been forthcoming from the beneficiary groups concerned.

The adoption of Strategy 4 places powerful constraints on a PVO's ability to execute the five recommended policies. It might be that the host country government's system of project development would adhere to the same general pattern; but this was not found to be the case in Niger, where the participatory content of projects rising through the system was relatively low. Although the principle of self-help is formally endorsed as a matter of government policy, it has not been used as a precondition for development assistance.

Policy Implications

The PVO community is diverse and heterogenous. In terms of the approaches taken, the goals adopted, and the resources channelled into projects, variation among PVOs is at least as great as the degree of difference between PVOs and official development approaches. Together with the documented variation in developmental impact in our sample, this underscores the need for comparative analysis across a broad range of development strategies in the policy review process of any agency that engages in the support of PVO activities.

The findings in the sample concerning benefit delivery, involvement of the rural poor, sustainability, and replicability suggest the following points having policy implications: 1.) The magnitude of the differences in success among projects was striking. 2.) The concentration of PVO activities on the rural poor was substantial. Close regulation by the host country government, however, (as required in Niger), limited the choice of target areas and populations. 3.) There was a wide range of project scores on the question of whether benefits would be sustained when PVO resources were withdrawn. 4.) Replication of the more successful projects was judged to be an expensive option, particularly in terms of the human resources needed; the limited evidence available from efforts to "scale up" PVO approaches was not encouraging.

These results underscore the fallacy of generalizing indiscriminately about PVO performance. The conclusions reached in this study, which indicate a preference for Strategy 1 or 2 and a recommended process of project development, should be reexamined and refined as a broader comparative data base is being accumulated.

Methodology. A major goal of this study was to identify a methodology for measuring PVO impact that offers a satisfactory compro-

mise between accuracy and cost. A compromise is required, inasmuch as almost unending amounts could be spent for marginal improvements in accuracy of measurement. Information on the time and resources involved in this cross-project study may offer some useful parameters for those responsible for planning and budgeting future impact studies. For field workers already familiar with the methodology, it should be possible to measure impact and its determinants, at the accuracy level of this study, for a sample of ten PVO projects in a single country, at a cost of between $30,000 to $35,000. (This assumes a team of two experienced data collectors working for five to six weeks in the field, aided by a local-hire field assistant, with an additional two to three weeks for analysis and write-up.) For a team new to the methodology, an additional one and one-half to two person-months would probably be needed prior to leaving for the field, which would add $9,000-$12,000 to the costs. Certain economies of scale could be realized in per-project costs by increasing sample size. These economies result from an increased familiarity with what information is needed and techniques to obtain it.

The methodology that has been developed here is too expensive to apply universally. Its utility is greater for summative evaluations designed to meet program and policy needs than for formative evaluations. The latter type of evaluation, aimed at improving the content of individual projects or the programs of specific PVOs, requires a much greater investment of time working with PVO home office and field staff. For summative evaluations, the usual lack of preexisting impact information places a premium on consistency in the collection and analysis of field data. In the absence of a randomized, experimental research methodology, there are obvious risks of error in attributing causality, i.e., giving credit for impact to the project itself. In these circumstances, one safeguard is to choose as evaluators persons with training in evaluation techniques and considerable experience in collecting field data in developing nations; preferably they should be without any likely project bias. The second safeguard is to equip evaluators with a conceptual framework, one that focuses not only on impact but on its possible determinants. With this as a starting point, the data collection effort can be streamlined considerably. Further efficiency could be achieved if the list of possible determinants is streamlined to include only essential factors that could be affected through policy or program decisions.

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